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THESIS

STANDARDIZED GUIDANCE
FOR THE ESTABLISHMENT OF A
NATIONAL HYDROGRAPHIC OFFICE IN DEVELOPING NATIONS

by

Mark L. Faye

September 1984

Thesis Advisor:

G. R. Schaefer

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The organization will be able to accomplish its objectives with a total of 23 employees divided into two organizational units. It is shown that a survey launch with six survey personnel is all that is necessary to achieve the identified near-term survey mission requirements. Time requirements will vary depending on whether survey operations can be conducted either on a year-round or seasonal basis--both scenarios have been identified.

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Standardized Guidance
for the Establishment of a
National Hydrographic Office in Developing Nations

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

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I. INTRODUCTION

A. WHAT IS HYDROGRAPHY?

1. Definition

Hydrography has been defined in a variety of ways and no concise, agreed upon definition has yet been established. Bowditch [Ref. 1, p. 848] defines hydrography as that science which deals with the measurement and description of the physical features of the oceans, seas, lakes, rivers, and other waters, and their adjoining coastal areas, with particular reference to their use for navigational purposes. A definition which relates more appropriately to this thesis is that hydrography is the science of measuring and depicting those parameters that are necessary to describe the precise nature and configuration of the seabed, its geographical relationship to the landmass, and the characteristics and dynamics of the sea. The above parameters include bathymetry, geology, geophysics, tides, currents, waves, and other physical properties of the seawater. [Ref. 2, p. 67] Regardless of which definition one chooses to use, the basic concept of a hydrographic survey is the same. Depth measurements are made whose horizontal positions have been accurately determined and with sufficient density so that the general bottom topography of the survey area can be inferred.

Coastal hydrography relates to water areas that in general are less than 30 meters in depth. Offshore hydrography can be regarded as having a limiting depth of approximately 100 meters and beyond this depth the term oceanic hydrography is used where oceanic implies the deep ocean realm.

2. Purpose

The principle reason for performing a hydrographic survey is to obtain information about bottom topography and adjoining coastal areas which will serve as the source for nautical charts, Coast Pilots, and other publications of importance to the mariner. Hydrographic survey data are also used in the study of marine resources and the marine environment.

B. BASIC OBJECTIVE OF RESEARCH

The purpose of this thesis is to establish guidelines to be used in the form of advice or other assistance by various agencies of the U.S. Government. This assistance would be offered to aid nations with limited or no present hydrographic capability in setting up a national hydrographic agency whenever such assistance is requested. Various other presentations have discussed either several aspects and guidelines in generalized form or just a few criteria in specific detail. At the present time, there appears to be no one source of information from which U.S. experts are able to extract all that is required.

The person or persons working on hydrographic agency establishment should have at least one of the following references on hand (preferably all of them) since these references deal with vital issues and specifications relating to the science of surveying and charting. These are the National Ocean Survey Hydrographic Manual (4th Ed.), Nautical Chart Manual (6th & 7th Ed.), Admiralty Manual of Hydrographic Surveying (Volumes I & II), and General Instructions for Hydrographic Surveyors [Refs. 3, 4, 5, 6, and 7].

C. NEED FOR UP-TO-DATE NAUTICAL CHARTS

Since the 1960s, there has been a dramatic increase in the demand for precise and accurate¹ surveys throughout the world. The majority of the nautical charts in use today are based on surveys conducted years ago, many dating back well over a century. Most of these surveys were done by colonial powers where the needs were clearly based on the priorities and requirements of the nation conducting the survey. Today the situation is dramatically different. A large number of countries achieved independence after 1960. One of the consequences of this freedom has been a withdrawal of much of the hydrographic support formerly performed by the major charting nations. Lack of support has led to the need of many of the developing nations, both with and without any hydrographic capability, to achieve their own self-sufficiency as many have been late developers in providing raw materials and other goods for export. Thus, the predominant needs are now based on local priorities and requirements which are daily increasing in number and scope. This set of circumstances is further aggravated by the fact that individual sovereign nations are now mainly responsible for surveying their own waters, especially since many nations which in the past did some international work now have greater domestic requirements than ever before, with little time or monetary resources to aid those most in need at the present time.

¹Accuracy indicates how well a single measurement or the average of a set of measurements agree with an adopted standard. Precision describes how well a single measurement agrees with another similar single measurement.

D. ASSUMPTIONS MADE IN ESTABLISHING GUIDELINES

The most important question to consider when studying the case of agency establishment anywhere is: What are the hydrographic requirements in this situation and what organizational approach would best satisfy these requirements? It is possible that establishment of a separate hydrographic service might not always be the best solution after close examination of the particulars is completed.² For the purposes of streamlining this thesis, a number of assumptions have been made. It is possible that one or several of these assumptions may not apply in the case of a particular nation. In that case, it will become necessary to take additional factors into account when developing any U.S.-sponsored report on recommendations and aid in regard to national hydrographic agency formation. The assumptions made are as follows:

- i. A natural approach is to make the hydrographic service fall under national governmental jurisdiction, rather than a private body, due to sovereignty considerations of offshore territory and resources. Therefore, all future considerations pertaining to hydrographic agency establishment brought forward in this presentation will be based on this fundamental assumption. This assumption is critical because published charts and related publications must have appropriate legal authority.
- ii. The nation presently has staff on hand knowledgeable in the various aspects of establishing horizontal geodetic control. Specifically, experience in the

²It serves no purpose to build up an elaborate and costly organization if it were underutilized in the long term, an example being a nation with limited shoreline and few ports. Different alternatives will be looked at later in this thesis.

establishment of geodetic control points needed in the field for offshore positioning is required and is presumed to exist. This experience is assumed because most nations already have a land-surveying department in operation. Even the lesser-developed nations tend to have expertise in this area, mostly due to influences of the mother country and needs in the past where locals were trained in land surveying procedures and methods. Other assumptions in this regard include availability of necessary equipment for measuring angles and distances, personnel capable of performing field measurements under any conditions and in remote areas, and computer support capability needed in the reduction of raw data to an appropriate geodetic datum and geographic position suitable for charting purposes.

- iii. All personnel acting in the capacity of surveyor have a good working knowledge of the sources of errors when using equipment to measure angles and distances. In addition, they have a familiarity with the appropriate methods to use to minimize the effects errors have on the measurements obtained during the survey.
- iv. Topographic mapping capabilities exist and are well-established in the nation. Cartographic skills are available covering the full range of expertise required for the production of nautical charts.
- v. The nation presently has the printing capacity needed to produce final versions of updated nautical charts. Any facilities already present which are now used to print topographic maps can easily be expanded to include space required for printing nautical chart products.
- vi. Adequate numbers of naval personnel are available from which the newly-created hydrographic agency

will be able to draw, such that the basic requirement of prior sea experience by some members of the hydrographic service will be satisfied. Sea experience is a critical factor: Survey planners require knowledge and experience in vessel appropriation, utilization and logistics support; and a survey party requires skills in all aspects of vessel operation and maintenance--these have a direct relationship to quality surveying efficiency and performance.

- vii. The hydrographic establishment will have the power to actively recruit personnel from the existing infrastructure. Geodesists, cartographers, and naval officers, all assumed to be presently available, can be easily transferred to the hydrographic department as the need dictates.

II. NATURE OF THE TASK

A. REQUIREMENTS JUSTIFYING AGENCY FORMATION

The specific requirements which have necessitated the need for more accurate surveys are many. The priority ranking of any of these over the others will be a function of specific factors in a particular nation. At the present time, charts are published periodically which cater to a particular user or class of users. A typical National Ocean Service (NOS) classification of charts [Ref. 8] is given below:

Small-Craft Charts--These specially designed charts are published with small craft information.

Conventional Charts--The conventional nautical charts are assigned to one of the following scale groups:

HARBOR CHARTS are published at scales of 1:50,000 and larger. They are intended for navigation and anchorage in harbors and small waterways.

COAST CHARTS are published at scales ranging from 1:50,000 to 1:150,000. They are intended for coast-wise navigation inside the offshore reefs and shoals, entering bays and harbors of considerable size, and navigating certain inland waterways.

GENERAL CHARTS are published at scales from 1:150,000 to 1:600,000. They are for use when a vessel's course is well offshore, but when its position can be fixed by landmarks, lights, buoys, and characteristic soundings.

SAILING CHARTS are at scales smaller than 1:600,000. They are plotting charts used for offshore sailing between distant coastal ports and for approaching the coast from the open ocean.

Tidal Current Charts--These charts present a comprehensive view of the tidal current movement in the respective waterways as a whole and also supply a means for rapidly determining for any time the direction and velocity of the current at various localities throughout the water areas covered, when used with accompanying Tidal Current Diagrams.

1. Safe Navigation and Trade

The nautical chart is absolutely essential as a medium of information and as a tool for all maritime traffic. It must contain all the information required for position fixing and route finding, for the avoidance of dangers, and the safety and ease of navigation. Schmidt [Ref. 9, p. 76] defines the different navigation subdivisions as follows:

Overseas navigation comprises ocean, marginal sea, and inland sea crossings.

Coasting refers to navigation in coastal areas, entailing navigation from headland to headland in sight of land, or sufficiently often in sight of land to fix the ship's position by land features.

Approach is defined as steering for the coast.

Entrance is steering into a channel or harbor.

Channel navigation is the way through narrow channels or canals.

Port navigation includes approaching berths and the actual process of berthing and unberthing.

Maritime trade relies on safe navigation. Today shipping still accounts for the largest percentage by far as a means of transporting goods and materials between nations. International trade is growing more every day as exploitation of resources worldwide continues to accelerate. Since the early 1960's vessel drafts have significantly increased, a direct result of both increased oil tanker traffic and larger vessels for transport in general which tends to reduce overall shipping costs and increase profitability. Many past surveys did not take soundings any deeper than drafts prevalent at the time the surveys were performed. As a result many past surveys, and the corresponding present day nautical charts, are grossly inadequate. In some cases these charts represent a hazard to navigation when used by today's larger and deeper draft vessels. The potential

risks involving the loss or damage of expensive cargoes due to shoaling or other navigation hazards makes trading along certain routes undesirable. The risks related to getting in and out of certain ports and the high costs of insurance associated with these new classes of ships result in a limitation of trade when inadequate nautical charts are used to represent the true nature of the bottom in these areas. Additionally, many nations now have requirements which call for adequate charts (based on varying specifications) to exist before ships may venture into their ports. At the present time adequate charts are not always attainable.

2. Increasing Local Requirements

The United Nations Law of the Sea Conference, although still in its negotiating phase, will undoubtedly have far-reaching effects upon all nations but places an extraordinary burden on maritime nations. The Law of the Sea Conference will define limits of the territorial sea, the Exclusive Economic Zone (EEZ) and the continental shelf. In general terms, the informal negotiating text cited by Kapoor [Ref. 10, p. 8] defines various limits of national jurisdiction as shown below.

The Territorial Sea is an adjacent belt to the land territory and internal waters over which the coastal State exercises sovereignty. Every State has the right to establish to breadth of its territorial sea up to a limit not exceeding 12 nautical miles, measured from the appropriate base lines.

The Exclusive Economic Zone is where the coastal State has sovereign rights for the purpose of exploring and exploiting, conserving, and managing the natural resources, whether living or non-living, of the seabed and subsoil and superjacent waters.

The Continental Shelf comprises the seabed and subsoil of the submarine areas that extend beyond a distance of 200 miles throughout the natural prolongation of the land territory to the outer edge of the continental margin.

An important aspect in the establishment of national boundaries from a legal standpoint is the delineation of both the mean low waterline and mean lower low waterline in datum determination. The different datums reflect one of the many problems of non-standardization which will be discussed later in reference to International Hydrographic Organization (IHO) objectives. The importance of a tidal datum is paramount since in most cases it is the basis in defining the legal boundary separating local, national, and international jurisdiction.

If the 200-mile EEZ were to become international law there would be an immediate and dramatic increase in the need for accurate surveys. The Law of the Sea Conference will make it mandatory for each nation to accurately define its 200-mile zone limit and produce charts which show the limits of national jurisdiction at a scale or scales with a resolution³ adequate for accurate determination. The magnitude of this problem in carrying out detailed surveys has been tabulated in the U.N. Report of the Group of Experts [Ref. 2], from which selected excerpts have been taken for illustrative purposes (Table I).

To realize the full benefits of the EEZ, each nation must first obtain accurate surveys and provide charts which will be prerequisite to any exploration. One needs to know the character and slope of the bottom if exploration is to proceed in a cost-effective manner. It will only be later that possible exploitation of the EEZ in these coastal areas

³Resolution is defined as the smallest unit to which an item can be measured.

TABLE I
Theoretical 200-mile EEZ Areas

(all areas in thousand km²)
(consider figures as order of magnitude values only)

Country ¹	Total Land Area	Exclusive Economic Zone	Area Increase (percent)
Argentina	2,776.9	1,164.5	42
Australia	7,686.9	7,006.5	91
Bahamas	13.9	759.2	5,448
Bangladesh	144.0	76.8	53
Barbados	0.4	167.3	38,825
Brazil	8,512.0	3,168.4	37
Burma	678.0	509.5	75
Chile	756.9	2,288.2	302
Colombia	1,138.9	603.2	53
Costa Rica	50.7	258.9	511
Cyprus	9.3	99.4	1,075
Ecuador	283.6	1,159.0	409
Egypt	1,001.4	173.5	17
El Salvador	21.0	91.9	437
Ethiopia	1,221.9	75.8	6
Greece	131.9	505.1	383
Guatemala	108.9	99.1	91
Guyana	215.0	130.3	61
Haiti	27.8	160.5	578
Honduras	112.1	200.9	179
Iceland	103.0	866.9	842
India	3,280.5	2,014.9	61
Indonesia	1,904.3	5,408.6	284
Ireland	70.3	380.3	541
Israel	20.7	23.3	113
Italy	301.2	552.1	183
Jamaica	11.0	297.6	2,715
Kuwait	17.8	12.0	67
Malaysia	329.7	475.6	144
Malta	0.3	66.2	20,943
Mexico	1,972.5	2,851.2	145
Morocco	446.6	278.1	62
New Zealand	268.7	4,833.2	1,799
Nigeria	923.8	210.9	23
Pakistan	803.9	318.5	40
Panama	75.6	306.5	405
Peru	1,285.2	786.6	61
Philippines	300.0	1,890.7	630
Saudi Arabia	2,149.7	186.2	9
Senegal	196.2	205.7	105
Singapore	0.6	0.3	59
Sri Lanka	65.6	517.4	789
Thailand	514.0	324.7	63
Turkey	780.6	236.6	30
United States	9,372.0	7,825.0	83
Venezuela	912.0	363.8	40

¹ "Country" refers also to territories or areas.

can be fully realized. Exploitation cannot proceed without exploration and its prerequisite of accurate charts to determine where such exploration is most apt to yield positive and fruitful results. The nautical chart and consequently the hydrographer plays a major role in all phases of resource exploitation. These include detailed surveys of the seabed configuration used in the location and placement of drilling platforms and wellheads, for the laying of pipelines and cables, and the precise location of lines of demarcation for bidding on tracts related to oil and gas exploration or mining concessions. The EEZ or any coastal waters also include biological resources, such as fishing grounds, which are becoming more important as nations look to the sea for increasing supplies and new sources of food for burgeoning populations.

3. Military Considerations

Military factors always need to be considered when dealing with coastal zone management. Precise nautical charts are necessary for both the individual nation and its allies so that movement of naval vessels is not impeded in any way, applying equally to surface and subsurface ships. With the complexity of today's international scene this requirement has taken on new significance and as the Exclusive Economic Zone and subsequent exploitation eventually becomes a reality, this will only increase the importance from a military standpoint. It will be tantamount for all nations to protect national interests in addition to personnel and equipment involved in exploitation activities offshore; this point cannot be overstated especially when one considers the enormous sacrifices that any sovereign state will need to make in diverting large sums of capital in providing the ways and the means to achieve hydrographic capability and future resource utilization.

An additional item of significance relates to the mandatory function of any nautical chart to accurately delimit all military zones. General shipping must be fully aware of exactly what routes are available for coastal navigation to insure that they do not venture into restricted military waters.

4. Recreational Activities

Recreational boating has forced an additional demand on the requirements of nautical charts, one that has been growing substantially in recent years. Clear portrayal of hydrographic features at large scales is becoming increasingly expensive, labor intensive and time consuming. Many ports worldwide are finding that an increasing percentage of nautical chart users fall into the category of the recreational boater or cruise vessel operator. Such an increase is a direct result of improved economic conditions worldwide, with the result that the requirements of local needs have superseded the more developed nation's needs regarding safe navigation in local waters of these developing nations. Cruise ships, with the obvious benefit to a developing country of placing one or more of its ports as a port-of-call, are also increasing their role as many routes are looking to expand, opening up more areas to tourists on an international scale. Before a captain will add a new port-of-call to a cruise itinerary, the captain must be assured that approaches to the port and pier facilities are adequately and accurately charted.

B. CHART UPDATE REQUIREMENTS

There are innumerable reasons why the need for accurate nautical charts is so paramount. Some of these have been alluded to previously in a basic sense. The predominant

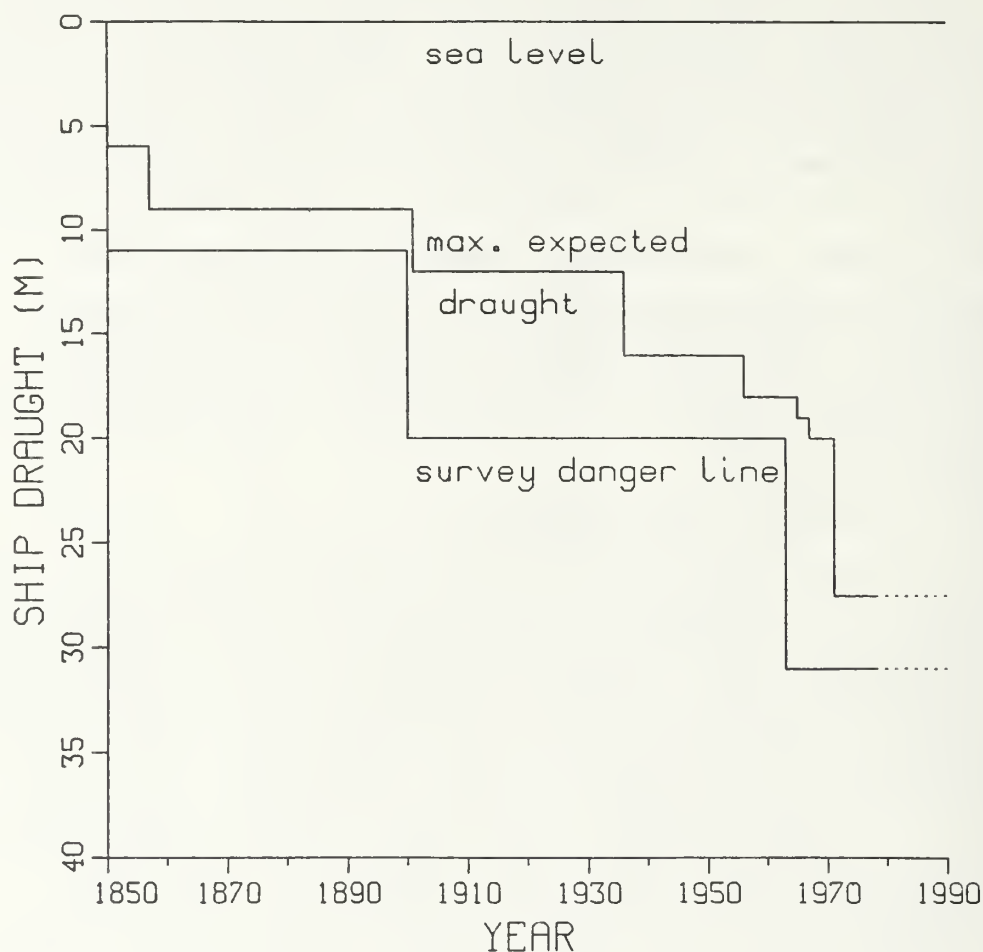
factors to consider include deeper draft vessels and condition of previous surveys which incorporated methods and procedures inappropriate and substandard given today's accuracy and precision requirements. Others involve the misuse of equipment, superficial quality control, and technicians making erroneous or inappropriate decisions due to the lack of in-depth hydrographic knowledge and expertise. In some cases, inappropriate decisions have led to enormous expenditures of additional capital, labor, and time which could have been avoided if a professional hydrographic viewpoint were considered.

1. Deeper Draft Vessels

The extent of hydrographic surveying in a port is typically a function of the relationship between the largest and deepest draft vessels utilizing the port, the associated depths of channels and harbor approaches, and the degree of stability of the bottom (Fig. 2.1) [Ref. 11, p. 5].

Ship captains very often utilize every inch they believe to be available for under keel clearance. Subsequently, this narrow margin demands a very high standard of accuracy. Time is money. Thus at times the captain will push the ship to the limit rather than waiting for a high tide to enter a port.

In areas where no changes in the bottom topography are known to occur, or where changes are systematic and predictable, pilotage within channels and subsequent berthing alongside a pier pose few problems--this is especially true where the port in question is utilized predominantly by local mariners and by piloted vessels. Unfortunately, there are many situations that alter the bottom topography creating shifting shoal areas and unstable channel conditions, often occurring to do changes in a river estuary, meteorological conditions, or the addition or



Survey danger line

Depths below which full search for
and examination of seabed dangers
were not considered necessary (m):

1850-1900	11
1900-1963	20
Since 1963	31

Dangerous wreck symbol on charts

Depth above wreck represented (m):

Until 1960	<14.6
1960-1963	<18.3
1963-1968	<20.1
1968-1976	<27.4

Figure 2.1 Ship Draft in Relation to Survey Danger Line

alteration of structures. Such factors work either in conjunction with one another or independently and have the net effect of changing sediment load capacities in the estuary, determining directional movement and speed of migrating sand waves, and altering longshore sand transport. Surveys need to be performed on a periodic basis to accurately portray such changes when these situations occur.

Catastrophic results could occur with the grounding of an oil tanker or hazardous chemical cargo vessel with the likelihood of severe damage to local beaches, fish populations, and related ecological factors. Damage could adversely affect the area for years after cosmetic cleanup has been concluded. Costs related to cleanup of a spill of even moderate magnitude can be millions of dollars. The situation becomes even more acute when one considers the amount of maritime traffic transporting similar cargoes passing in and out of major ports with an occurrence approaching one every few minutes on a continual basis. The possibility of bearing cleanup costs could dwarf the costs involved in maintaining updated charts on a periodic basis.

Being aware of tidal fluctuations makes it easier to maintain proper port management so larger vessels will be able to utilize this information and decrease potential downtime in docking offshore. Automatic recording tide gages, direct-reading current meters, and appropriate devices for recording parameters of temperature, salinity, and suspended silt will allow for more effective work in the measurement of tidal movement and water composition.

2. Condition of Prior Surveys

More than one half of the nautical charts in use today are at least partially based on obsolete surveys; some areas have not been resurveyed since the eighteenth century. Surveys performed as recently as the 1930s contain many of the same basic flaws as those done 200 years earlier.

a. Accuracies in Position and Depth

There are a variety of reasons for which to doubt the accuracy and precision of much of the information presently being portrayed on nautical charts. It is possible to have cases of precision without accuracy or accuracy without precision, neither of which would necessarily yield the true representation of the actual value. It is the simultaneous occurrence of both factors above being demanded in present specifications and standards worldwide. If only one measurement of a quantity is available it is difficult to ascertain whether that measurement is either accurate or precise.

Shoreline mapping, positioning, and depth are three areas where obsolete survey methods from the past might have led to inaccuracies in present day charts.

- i. **Shoreline Mapping**--Shoreline mapping in the past utilized methods considered crude by today's standards. It is likely that the position of the charted waterline is considerably in error if modern photogrammetric methods have not been employed.
- ii. **Positioning**--Past methods and procedures frequently provided questionable positions. Electronic positioning system accuracies, questionable regarding present manufacturer's claims, were undoubtedly of vastly lower quality in the past. Errors in position of 0.3 miles on a chart used for merchant marine navigation across the open ocean might be perfectly acceptable, but for nearshore piloting and navigation, this magnitude of positioning accuracies is totally unacceptable. Loran positioning is utilized most often in coastal navigation. With Loran systems, precision is very high but accuracy is often very low, meaning a ship obtaining a fix

with Loran may be able to navigate back to the exact same location but daily changes may prevent even this from happening. It is unlikely that correct values of latitude and longitude could be obtained for that position, although hyperbolas are drawn around a known point so that any discrepancy between geographic positions obtained by Loran rates and the true geographic positions can be kept to a minimum. Conversely, accuracy is imperative in performing hydrography so that soundings obtained are able to be represented by geographic coordinates which correlate to exact positions plotted on a nautical chart.

- iii. Depth--Lead line soundings, on which a vast majority of the older surveys are based, are in many cases poor in accuracy and have not been superseded. Slant measurement of depths often have been recorded in areas of strong currents or due to sounding vessel speed.

b. Methods and Procedures

Another factor relating to the accuracy of data deals with proper calibration techniques of various types of instrumentation used in determining position and depth information. Echo sounders on small vessels are usually calibrated for shallow water by the bar check method. By lowering the bar to premarked known depths the accuracy of the echo sounder is determined. Bar check data are also used to determine velocity correctors for the appropriate speed of sound within the water column to obtain the true depth below the echo sounder as a function of time. In deeper water, greater than that which the bar check can practically be utilized, the water characteristics can vary

to a large degree. Some other method must be used in conjunction with the bar check to insure that the correctors used are appropriate when sounding in deeper water. Velocity in seawater is a function of temperature, salinity, and pressure. It is essential that measurements throughout the water column be made periodically by use of an oceanographic cast or velocity sensor in order to correctly determine the velocity profile. In unstable areas of frequently changing characteristics in temperature and salinity, particularly in estuary environments or in locales with monsoon-type climate conditions, one of these methods should be employed frequently to detect changes over time. In summary, bar checks are useful in determining consistency in depth readings on a daily basis and are quite appropriate in deducing velocity correctors by themselves in areas of shallow water. However, in deeper areas other means need to be used to determine velocity correctors.

For shallow water surveys, a necessary test to be performed is settlement and squat of the sounding vessel. One needs to know the depth below the water line of the transducer when the vessel is dead in the water so that final true depths can be determined after raw depths have been corrected for changes in sound velocity. Since bar checks are performed at a stationary point, additional settlement and squat correctors at varying vessel speeds are required to reduce soundings taken on line when the vessel is in motion. An important prerequisite is to log the speed of the vessel at all times when hydrography is being run, otherwise the final reduced depths cannot be obtained.

Calibration of base lines, when using electronic navigation distance measuring equipment, is another necessary function which at times has been overlooked. Without a base line calibration both before and after the survey, there is no way to determine whether or not the electronic

navigation equipment is functioning properly. Daily checks of the ranging system are necessary; these checks performed at the beginning and end of each survey day are used to verify the consistency of the daily data, as well as making it easier to determine which data are valid if discrepancies should occur.

c. Inappropriate Use of Equipment

In the past, there has been a tendency to use tried methods and systems beyond the limits of their capability; this is especially true when methods and systems developed to solve problems from the past are used in dealing with activities in today's world with greater standards of accuracy. Examples of this misuse have been written by Haskins [Ref. 12, pp. 22-23]:

The use of the 2-MHz phase comparison radio positioning systems, initially developed for inshore coastal surveys, for far offshore exploration surveys with the associated problems of sky waves, night effects and ambiguity of lane count in remote, unreferenceable areas.

The use of 100-kHz phase comparison navigation systems for higher precision of survey control, something they were never intended for. These data stay on record for years and are later extracted and taken as truth.

The use of self-recording tide gages, designed for deployment in protected inshore sites, in exposed areas offshore with usually unsuccessful results.

The measurement of water depths critical in engineering design in very deep water by wide-beam echo sounders through water columns of unknown or indeterminate characteristics.

The use of graphical solutions for positioning measurements stemming from the days of optically measured position lines long after multi-line radio positioning became available.

The ever increasing pressure to use acoustics through the water for various end results utilizing, inevitably, equipment of a previous generation.

3. Quality Control

There have been numerous cases of shortcomings commonly encountered in contracting work to private organizations, particularly in the absence of personnel knowledgeable in checking specifications for and the results of surveying work. Several case histories have been cited by Sathaye [Ref. 13, pp. 17-18]:

A port authority awarded a contract for new berth construction to a reputed firm. After project construction had already begun, a hydrographic expert found that the berth alignment was normal to and in the direct path of the sediment transport flow pattern. Only timely modification enabled the situation to be corrected.

A large oil company awarded a contract for dredging and a post-dredging survey. The firm's result claimed that the channel was indeed dredged to the projected depth. The port hydrographer, upon checking the survey, found that depths 1 meter shoaler than the projected depth still existed.

In its desire to accommodate larger vessels at new facilities under construction, one port authority decided to deepen a channel from 41 to 49 feet at a cost of \$3.5 million. The port hydrographer, after analyzing the vessel drafts and prevailing tidal conditions, found that a 42-foot depth would be sufficient without hampering navigation of larger vessels saving \$3.2 million, 90 percent of the original estimated cost.

In the case of a poorly investigated seabed, an oil pipeline fractured under pressure due to the presence of a soft strata on the seabed. Rectification cost the company a great deal whereas the cost of bottom sampling would have been minimal by comparison.

Quality control related to all aspects of coastal zone management is of paramount importance, regardless of what type of survey is being performed. This control has to be established in any prospective hydrographic organization at all levels and adhered to rigidly without reservation, particularly when attempting to meet today's high standards of position and depth specifications.

III. STRATEGIC PLANNING GUIDELINES

A. IMPORTANCE OF STRATEGIC PLANNING

Strategic planning is the formalized, long-range planning process to define and achieve organizational goals. Basic important questions relating to strategic planning can be posed. Which groups represent the primary users of our nautical charts and who should they be? Which of the available courses of action will be most consistent with our strategy? One of the most important reasons why strategic planning has become critical is that it enables managers to prepare for and deal with the rapidly changing environment in which the hydrographic organization operates. These changes can be in economics through budgetary cuts, legal decisions, and international laws and regulations.

A country's decision-makers must understand the benefits to be derived from the formation of a hydrographic service. There are both short-term and long-term advantages to be achieved in this regard. Since financial resource commitment is necessary in establishing this service, it is likely that political decisions will play a role in funding capability. For this reason, administrators at appropriate governmental levels must be made aware that only through a stable and efficient hydrographic organization will benefits of economic development such as exploitation of offshore resources and trade expansion become a reality. The need for hydrographic service capability having previously been established, it is now appropriate to review mission requirements and objectives contingent on the identified needs.

B. PURPOSE OF THE ORGANIZATION

The broad aim of a hydrographic agency is to be a complete, self-sufficient oceanographic information service in the long term. This aim provides the means with which to gain a thorough and complete knowledge as it relates to all aspects of the marine environment for the benefit of science, commerce and industry. As this aim is only meant to be achieved in the long term, individual priorities and associated time requirements will follow a sequential buildup in order that this goal will eventually become reality.

C. ORGANIZATION MISSION REQUIREMENTS

There are two positions from which one could relate mission requirements--wide versus narrow scope. In its broader context, the mission of the newly created hydrographic service should contain the following elements:

- i. The production of nautical charts based on accurately performed hydrographic surveys to ensure safe navigation in all applicable areas falling under national jurisdiction.
- ii. Planning and surveying of ports whose establishment and upkeep is necessary to ensure economic viability in international trade.
- iii. The determination of maritime limits of the territorial sea, the EEZ, and the continental shelf as called for by the present Law of the Sea Conference negotiations and the acquisition of data to acquire knowledge of resource potential in this marine environment.
- iv. Collection of information and data useful in the protection of the marine environment.

The guidelines to be addressed will be limited and deal with the narrowest scope of the above long-term mission requirements, that being the production of nautical charts to ensure safe navigation, except in cases of special interest or concern. All other items above have been previously addressed as to their relevance and importance in the introduction.

D. MISSION OBJECTIVES

An objective is defined as a target that must be reached if the organization is to achieve its goals as defined by its mission. Regarding the mission of nautical chart production, objectives can only be met if approached from the standpoint of development through a series of planned stages achieved progressively over time. It is logical and necessary that normal progression will be accomplished from modest beginnings, with planned growth evolving as a function of emerging needs, financial considerations and constraints, and manpower availability. The objectives are expressed as a function of both likely priorities and time, and outlined below as five basic steps of planned stage development [Ref. 2, p. 84].

Planned Stage Development

- i. The identification of the appropriate agency to act as the focal point for hydrographic matters.
- ii. The training of essential personnel which would initially be very few in number.
- iii. The establishment of a minimum service to survey and chart ports and harbors, approaches to ports and harbors, and inner coastal waters.
- iv. The expansion of the service to survey and chart outer coastal waters and offshore areas.

- v. The further expansion of the service to fully embrace bathymetric and geophysical surveys of oceanic waters.

The above development sequence is directly dependent on specific need priorities identified previously in this thesis. If the overriding need is resource identification, exploration, and development or is based on military considerations, then the last two steps in planned stage development listed above likely would take on an increased priority. Many resources are located well offshore and a particular nation might need to begin surveys offshore in conjunction with port facilities inshore if resource development is the most demanding priority. An extra initial burden of increased equipment and personnel would then occur since offshore survey work requires a different positioning system, equipment associated with bathymetric and geophysical surveys, and a larger vessel with its increased crew requirements, fuel consumption, and maintenance. Military priorities would demand accurate and complete bathymetric surveys to fully represent the configuration of the seabed with all pinnacles, wrecks, sand wave positions, and other least depths precisely portrayed to allow for safe navigation of both surface and subsurface ships.

The primary scope of the mission has been identified as the production of nautical charts to ensure safe navigation. It is now appropriate to identify the mariner's requirements of such a chart.

E. THE NAUTICAL CHART

As identified in the introduction, safe navigation and trade requires that the nautical chart give information essential to all vessels including data for position fixing, route finding, and safety and ease of navigation. Detailed

recommendations regarding essential information to be portrayed on a nautical chart are a function of chart use and navigation subdivision classification. Various IHO Technical Resolutions have identified specifications involving the portrayal of this essential information.⁴ Schmidt [Ref. 9] advises that any list serve only as a framework for selecting the required information and not to be used as a definitive check list. Regardless which recommendations a charting division might choose to adopt, it will be necessary to determine the purpose of the chart so that appropriate items to be portrayed as needed for position fixing, route finding, and navigation safety can be identified.

Production of a precise nautical chart requires that an equally precise quality of survey data be obtained. It is necessary to specify both positioning and sounding accuracies and sounding intervals of the survey. It is recommended that all nations utilize survey standards and specifications adopted by the latest edition of the IHO Special Publication No. 44 [Ref. 14]. Book 1 of this publication is entitled The IHO Standards for Hydrographic Surveys and "...provides guidance relative to the minimum acceptable standards for surveys..." and Book 2, The Classification Criteria for Deep Sea Soundings, offers "...a uniform set of criteria for classifying bathymetric soundings after they have been taken, for record purposes, and the guidance of cartographers, scientists and other users" [Ref. 14].

⁴For another viewpoint, it is recommended that the Report by the German Hydrographic Institute Working Group be consulted. Although not duplicated here, the three tables from that report can be useful in dealing with depiction of chart information and can be found in Ref. 9, pp. 78-80, Tables I, II and III. It should be noted that in some cases items identified in this Working Group Report occasionally conflict with existing IHO Technical Resolutions.

The IHO plays a major role in fostering international cooperation in the standardization of hydrographic symbology portrayed on the nautical chart. Through its forum of regular conferences every 5 years, they have been successful in promoting similarity in production of charts and related publications: These items include overcoming language problems; standardizing symbols and abbreviations; standardizing light lists; written descriptions of coasts, ports and dangers; directions for safe sailing; and tidal information. [Ref. 15, p. 480]

The actual procedures and specifications mentioned previously will be determined by the purpose for which the nautical chart is to be used. Shallow areas constituting a hazard to navigation must be very precisely sounded whereas the deeper areas are sounded with the broader aim of obtaining an accurate portrayal of the representative outline of the seabed. In contrast, for a bathymetric survey all areas should be surveyed with equal precision. In either case, it is necessary to first determine the scale of the chart. This determination will then enable one to define the smallest feature that can be represented at the chosen scale, and sounding standards meeting IHO specifications can then be determined and used in conducting the survey.

It is advisable to follow some basic rules of thumb in the preparation of nautical charts. Several of the fourteen rules that follow have been summarized from Newson [Ref. 16, pp. 356-358].

- i. Each detail must be assessed for its usefulness to some important class of user in the context of the surrounding details and the scale of the chart.
- ii. Chart format sizes and specifications according to IHO specifications of the International Chart should be used whenever possible (see Ref. 17).

- iii. Detailed depth information in required areas should be shown in a specific order. Least depths on shoals and in navigable channels should be shown first, followed by a specified range of depth curves, and then by selected soundings showing the trend of bottom features not brought out by the depth curves.
- iv. All deeps need to be accurately depicted on the survey so that determination can be made by the chart compiler as to whether the deep is a significant feature which should be shown on the final version of the chart.
- v. Small-scale charts should show a complete overview of the surrounding marine environment to aid in piloting.
- vi. Coastal navigation charts must not have areas of great traffic density or course alteration points located at the junction of adjoining sheets.
- vii. Coastal approach charts must depict prominent land features necessary for taking bearings and ranges to aid in vessel piloting.
- viii. If possible, all the significant variations of bottom quality should be identified to aid in anchoring and when navigating in shoal areas. This information is of great interest to fishermen.
- ix. The depiction of all of a port should be shown on the same chart whenever possible.
- x. Adjoining nautical charts need to have significant overlap between them to aid in navigation. It will be the job of the chart compiler to judge what overlap is significant in a particular situation.
- xi. A chart scale should be selected that depicts detail in accordance with the purpose of the chart.
- xii. Topographic features are of greatest interest to the navigator when piloting along the coastline

and these features assume less importance with distance from the water. It is the unique or unusual feature of the topography that the mariner needs for determining position and thus must be portrayed.

- xiii. Differing lettering types and weights should not be used to represent specific facts on a nautical chart as they are often difficult to distinguish and could lead to chart ambiguity.
- xiv. Most charts must be updated periodically, but unless absolutely necessary should not be accomplished by the commission of another survey. One effective method in disseminating relevant information is by corrections issued as attachments to Notices to Mariners. Dissemination can easily be accomplished through the set-up of a local information gathering unit who can relate any useful items to the appropriate charting authorities.

IV. PLANNED STAGE DEVELOPMENT

A. OVERSEER OF HYDROGRAPHIC SERVICE

There are several alternative solutions to the question of which governmental department will be the parent organization to the newly established or expanded hydrographic service, keeping in mind the assumption of national jurisdiction made in the introduction.

Historically, it has been logical for a country to utilize its naval organization to administer hydrographic affairs. Any beginning hydrographic service will be heavily involved in problems of vessel acquisition, logistic support, etc. These problems are much easier to handle and plan for when under the direction of a national military establishment. Advantages include dealing with procurement and overhauling of vessels so that they can be utilized in a hydrographic mission, wide-ranging access to sea-experienced personnel, and echo-sounding and navigation position-fixing equipment. There is a recognized hierarchy in the defense community within which a hydrographic agency could adapt and adjust easily. Personnel are trained to do exactly what they are told. Following instructions precisely is especially crucial in hydrography where attention to detail can make the difference between success and failure of a survey and subsequent chart product.

The greatest disadvantage of naval jurisdiction is that in times of war or national emergency critical personnel may not be available to the hydrographic service. Even in peacetime, military personnel rarely perform more than a 3-year tour of duty before being transferred somewhere else. It is always difficult to maintain precise planning and

scheduling if the prospect of continued interruption in personnel is a likely occurrence. In addition, pursuit of scientific knowledge is not always one of high priority to the defense establishment and as such the agency would not always receive the support necessary to carry out its full range of scientific functions needed in hydrographic study. Recruitment in geodesy, surveying, cartography, and other typically non-military fields could pose problems for the military in staffing the agency.

In contrast, there are advantages to civilian control under direction of either the geodetic, topographic, or cartographic agencies. Highly trained and competent civilian personnel can be counted on to provide a continuum to the staff with which the hydrographic agency can work to accomplish its mission in a smooth-flowing and efficient manner. There is also a greater degree of flexibility in a civilian environment and this becomes important when dealing with problems posed by rapidly-changing internal and external environments. Good managers are hard to come by and thus the agency must strive to maintain these management people on a career basis.

Using the IHO 1982 Annual Yearbook [Ref. 18], parent organizations of respective national hydrographic agencies have been identified as members of the IHO (Table II) or as nonmembers (Table III). Many of the nations listed do not presently have a hydrographic agency per se. Some agencies are strictly port authorities and others have only a minor semblance of hydrographic capability. Civilian jurisdiction has been broken down as follows: Marine--marine and port authority; Survey--survey and public works; Transport--transport, trade and industry, justice, and communications; and Oceans--oceans, fisheries, and environment.

TABLE II

Parent Body Overseeing Hydrography of IHO Members

<u>Ccountry</u>	<u>Military</u>	<u>Civilian</u>			
		Marine	Survey	Transport	Oceans
Argentina	X				
Australia	X				
Belgium			X		
Brazil	X				
Canada					X
Chile	X				
Peoples Rep of China				X	
Cuba	X				
Denmark	X				
Dominican Republic	X				
Ecuador	X				
Egypt	X				
Finland				X	
France	X				
Federal Rep of Germany				X	
Greece	X				
Guatemala			X	X	
Iceland				X	
India	X				
Indonesia	X				
Iran				X	
Italy	X				
Japan				X	
Malaysia	X				
Netherlands	X				
New Zealand	X				
Nigeria	X				
Norway					X
Pakistan	X				
Peru	X				
Philippines	X				
Poland	X				
Portugal		X			
Rep of Korea				X	
South Africa	X				
Singapore		X			
Spain	X				
Sweden				X	
Syria				X	
Thailand	X				
Trinidad & Tobago			X		
Turkey	X				
USSR	X				
UK	X				
USA	X			X	
Uruguay	X				
Venezuela	X				
Yugoslavia	X				
Zaire				X	

TABLE III

Parent Body Overseeing Hydrography of Non-IHO Members

<u>Country</u>	<u>Military</u>	<u>Civilian</u>			
		Marine	Survey	Transport	Oceans
Algeria	X				
Bangladesh				X	
Barbados		X			
Benin				X	
Bolivia	X				
Burma	X				
Cameroon				X	
Colombia	X				
Congo				X	
Cook Islands		X			
Costa Rica		X			
Cyprus			X		
Cambodia			X		
El Salvador			X		
Ethiopia				X	
Fiji	X				
Gabon		X		X	
German Dem Republic	X				
Ghana		X			
Honduras			X	X	
Ireland		X			
Israel				X	
Ivory Coast	X				
Jamaica			X		
Jordan		X			
Kuwait				X	
Lebanon			X	X	
Malagasy Rep			X		
Maldives		X			
Republic					
Malta		X			
Mexico		X			
Morocco			X		
Nicaragua	X				
Panama			X		
Papua				X	
New Guinea					
Paraguay	X				
Romania		X			
Sri Lanka					X
Sudan			X		
Tanzania		X			

The case for military or civilian jurisdiction must now be decided. Considering nations with present IHO membership, 65.3 percent have hydrographic services under military jurisdiction while only 34.7 percent fall under some form of civilian control. In contrast when looking at those nations not belonging to the IHO, 78.0 percent fall under civilian authority while just 22.0 percent have military ties. Evaluation of the above statistics, in light of the previous discussion of military versus civilian applicability, strongly influences the decision regarding jurisdiction. Nations which presently do not belong to the International Hydrographic Organization are most likely to be the ones seeking aid and advice in setting up a full hydrographic service. The present skeleton service of these nations is predominantly in the hands of a civilian authority. In addition, hydrographic needs are an increasing function of local requirements, specifically trade and resources which naturally lend themselves to civilian control due to economic considerations. Based on these points, and the assumption made earlier that most nations have an established geodetic, topographic, or cartographic capability, command from the civilian sector of government seems a natural choice in most cases.

B. ORGANIZATIONAL STRUCTURE AND FUNCTION

There are numerous ways in which any organization can be structured and a hydrographic organization is no exception. A review of those in operation today show a wide diversity in design. The proposed organization (Fig. 4.1) attempts to achieve a balanced mix of expertise incorporated into a smooth-flowing, efficient, well-managed, production oriented agency.

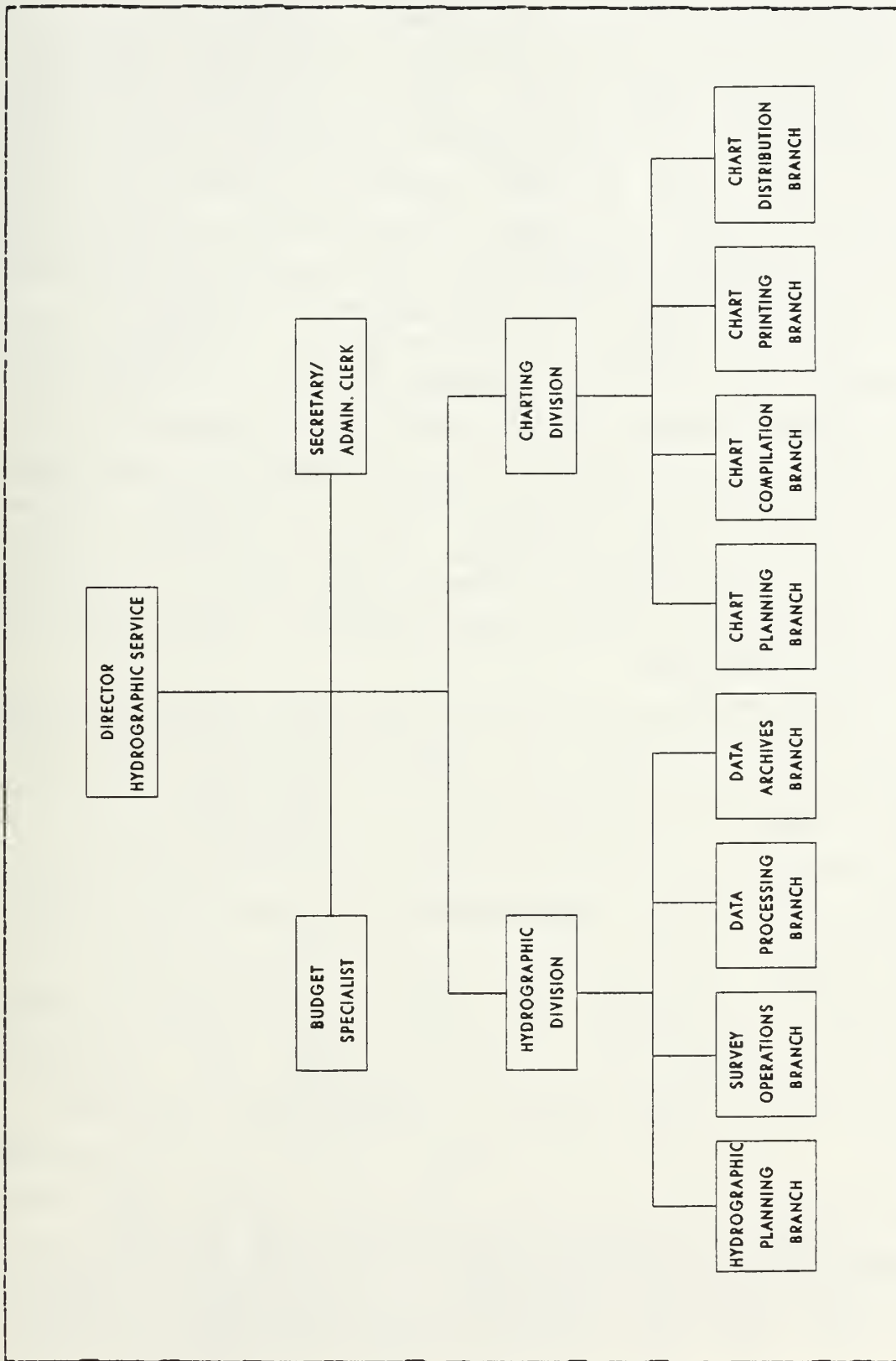


Figure 4.1 Hydrographic Agency Organizational Chart

Nations attempting to establish hydrographic capability need people of action to get charts revised and updated to present standards, not to create an additional burdensome administrative bureaucracy. Such an organizational structure reflects the primary mission involving nautical chart production. Later on, other scientific disciplines such as oceanography could be easily integrated as a new division or as an independent agency--this will be purely a function of the circumstances of the individual nation involved.

Lean staff support is recommended as a lesson to be drawn from the business successes of today. A combination of a minimum number of highly-skilled top management personnel and a wise, decisive, and relatively independent team of production managers capable of successful problem-solving is all that is needed. Working together, this mix will be a major factor in determining success in management and production as well as high productivity and career motivation of employees.

The director must have time-tested and proven management skills and abilities. It is highly recommended that this person also have both experience in hydrographic sciences and a degree in a related field such as natural sciences, engineering, or surveying. Only if the Director is fully aware of the overall requirements necessary to fulfill the organization's mission can he or she then obtain, through recruitment, personnel most likely to aid in mission accomplishment. Management skills relating to the initial set-up are also important, as any decision made at the beginning often sets the tone regarding organizational long-term values. Responsibilities include evaluation and procurement of equipment for both survey and survey-support functions, vessel acquisition, budgetary knowledge for personal decision-making and recruitment of a budgetary specialist, recruitment of the two division heads, and the foresight to

plan for future organizational growth.⁵ Such planning includes arrangement for the training of newly acquired personnel needed in the long term in order to create a fully qualified, multi-functional working group capable of interdisciplinary functioning, allowing for far greater flexibility in times of crisis or changing priorities.

The overwhelming single reason for success in any organization is the selection of the right individual at the helm. Peters and Waterman [Ref. 19] state emphatically, with numerous examples to back up their claim, that it is the value structure established under a strong, knowledgeable, visionary leader which is paramount to success. The director of the agency will need to have such qualities to instill these ideas into the organizational fabric so that success will be a natural consequence of hard work and dedication. The right value structure permeates the organization and leads to personnel stability, career motivation, and higher quality and productivity. A nautical chart product is no exception and highly motivated individuals inspired by the right leader are capable of things that they as individuals might not have thought probable to achieve.

Current management theory states that the first crisis point to occur in any organization as it increases in size and age is a "crisis of leadership." It can occur because "...the founders, incapable or unwilling to change their management styles, may have to step aside in favor of a strong manager who can refocus the organization" [Ref. 20, p. 370]. The importance of the right management person at the top from the beginning is again underscored; one who is

⁵Strong, decisive leadership is required at the division level if the lean organizational staff is to succeed. Unless the Director has these qualities it is unlikely that he or she will be able to identify these same qualities in others. Additionally, it is natural to assume that any top quality manager might resist taking a division head position if it was perceived that the Director had less than top quality management skills and abilities.

able to adjust to changing needs and priorities easily with minimal organizational disruption.

Two divisions are intended to handle the full range of production functions necessary to create the final nautical chart product; these are the Hydrographic and Charting Divisions, each with its own area of responsibility.

1. Hydrographic Division

The Hydrographic Division performs functions related to all aspects of survey operations and is subdivided into four branches.

a. Hydrographic Planning Branch

The functions of this branch include the technical and logistical planning necessary before a survey project is to begin. Once the branch has been made aware that a particular survey is needed to support chart revision, many functions have to be performed from the planning aspect in support of the upcoming survey.

All items relevant to the historical record of the area must be assembled. Among these are prior surveys, previous charts of the area and associated junctioning charts, geodetic control data, and all other additional information which is pertinent when proposing a plan of attack for the survey.

A geodetic control package is required which identifies all existing horizontal control and ascertains whether the control still exists by examining station recovery notes. As a first priority, the geodetic field people are notified so that additional control can be established if necessary. Geodetic information is needed to meet requirements for both photogrammetric control for shoreline mapping and hydrographic survey positioning.

The planners also activate the tides section to accumulate necessary historical tidal information and to determine tidal zoning boundaries--this information will be forwarded on to the photogrammetric section if needed. .

The next determination is whether shoreline maps presently on file are adequate or whether new shoreline maps are needed. If needed, this step would include planning for new tide-coordinated photographs of the area through which photogrammetric techniques could be applied in generating the updated shoreline maps. Although the actual photogrammetric field work planning does not originate in this branch, the planners are responsible for the logistic support of the field unit through arrangements involved in procurement of necessary equipment. Logistic support can be arranged through some other government agency or through contract, depending on feasibility and availability.

All informational inputs are accumulated by the Hydrographic Planning Branch. It then becomes the responsibility of this branch to write the Project Instructions to be used by the survey team in the field based on this total accumulated information. These instructions attempt to cover most of the contingencies which could arise and dictate surveying specifications which need to be followed in the field. The office staff also generates a Presurvey Review which identifies areas and items which need to be investigated further to prove or disprove an item on a previous chart edition which might be in dispute regarding its validity. Reported shoal areas are identified and investigative requirements related to the search and identification procedures in these areas are spelled out clearly to give the field unit as full a set of guidelines as possible.

The Marine Support Specialist also plays a critical role in the Hydrographic Planning Branch with such

varied responsibilities as conducting logistical support for the survey team; making appropriate decisions regarding type, function, and subsequent procurement of vessel; and preparing the survey vessel with an appropriate complement of hydrographic equipment necessary to accomplish the survey as described in the Project Plan.

b. Survey Operations Branch

The Survey Operations Branch will be responsible for all aspects of field operations⁶ and will be organized in five sections.

(1) Geodetic Section.

Functional requirements of this section relate to field work needed in establishing or verifying control information to be used in photogrammetric control and by the survey party in position fixing. The personnel might need to go into the field in advance of the hydrographic survey team when deemed necessary in areas of sparse or no control. The land surveying capabilities of these field personnel must therefore include expertise in the full spectrum of methods with which establishment of adequate geodetic control can be accomplished. Ground survey methods include traverse, triangulation, and trilateration. Knowledge in these methods is absolutely essential, and if other satellite-aided methods are available, these too should fall within the realm of expertise of the surveyor. Any particular method to be employed will be a function of available alternatives, past experience, and applicability to the particular situation. Again, cross-functioning will exist whereby this information is added to the presurvey planning package before the survey begins. After survey

⁶It is recommended that the IHO's Standards of Competence for Hydrographic Surveyors [Ref. 21] be used as the guide in evaluating experience levels in hydrographic surveying.

data acquisition geodetic processing might again be required to reduce and verify any field-generated geodetic measurements and positions.

(2) Tides Section.

Responsibilities include functions which need to be performed both before and after the actual survey. Tidal zoning recommendations are made based on historical data prior to actual tidal data acquisition. Zoning is based on historical data and information concerning the nature of the coast and the interrelationships of varied meteorological and geographical effects which play a role in determining the actual tides. The section needs to compile a full historical tidal package including data of predicted values and location of primary stations and any secondary locations which might still be operating. The historical record and zoning information is then forwarded back to the hydrographic planners to be included in the total presurvey package. After completion of the survey, the Tides Section again becomes involved to analyze the actual tidal record from all tidal stations. This analysis produces the real-time tidal correctors which are applied to the raw survey sounding data later to be compiled for the nautical chart.

(3) Photogrammetric Section.

Whenever applicable, depending on requirements, this section will have the function of flying the tide-coordinated photography and producing shoreline maps. The photogrammetric mapping should be performed after both control and tidal information has been received. Determination of panelling requirements for photo-identification needed to achieve satisfactory control coverage, for the accurate portrayal of shoreline positions, would then be made easier. In addition, it could be possible to obtain positions of certain hazards to navigation which might be

clearly visible on the photographs. The final shoreline maps are forwarded to be included along with all other inputs to the total presurvey package.

(4) Hydrographic Survey Section.

After all the preliminary source information has been amassed, the actual field survey can begin. The functions of this section include conducting the actual survey which includes sounding and position fixing as per specifications in the Project Instructions. Field processing of the raw data is a quality control function whereby the data are scanned daily in order to examine all positions and depths, discarding those that appear to be in error. The field sheet is also examined daily to determine whether bottom features require further investigation. Close examination is important to accurately represent a true portrayal of the bottom and also to verify that all least depths are identified and represented on the field sheet. Soundings are adjusted for predicted tides and plotted on the field sheet. The National Ocean Service hydrographic survey flow chart (Fig. 4.2) can be used as a field checklist to make sure all necessary functions have been carried out as required.

(5) Miscellaneous Tasks.

Various additional tasks might be required, depending on the Project Plan and Project Instruction specifications listed in the presurvey package. One such task might involve forwarding the present edition of the Coast Pilot and any special project needs on to the survey as part of the total package. Instructions must specify whether bottom samples need to be taken and if so, what sampling density is necessary. A user evaluation is also performed and forwarded with the Coast Pilot information to the survey unit.

HYDROGRAPHIC SURVEY FLOW CHART

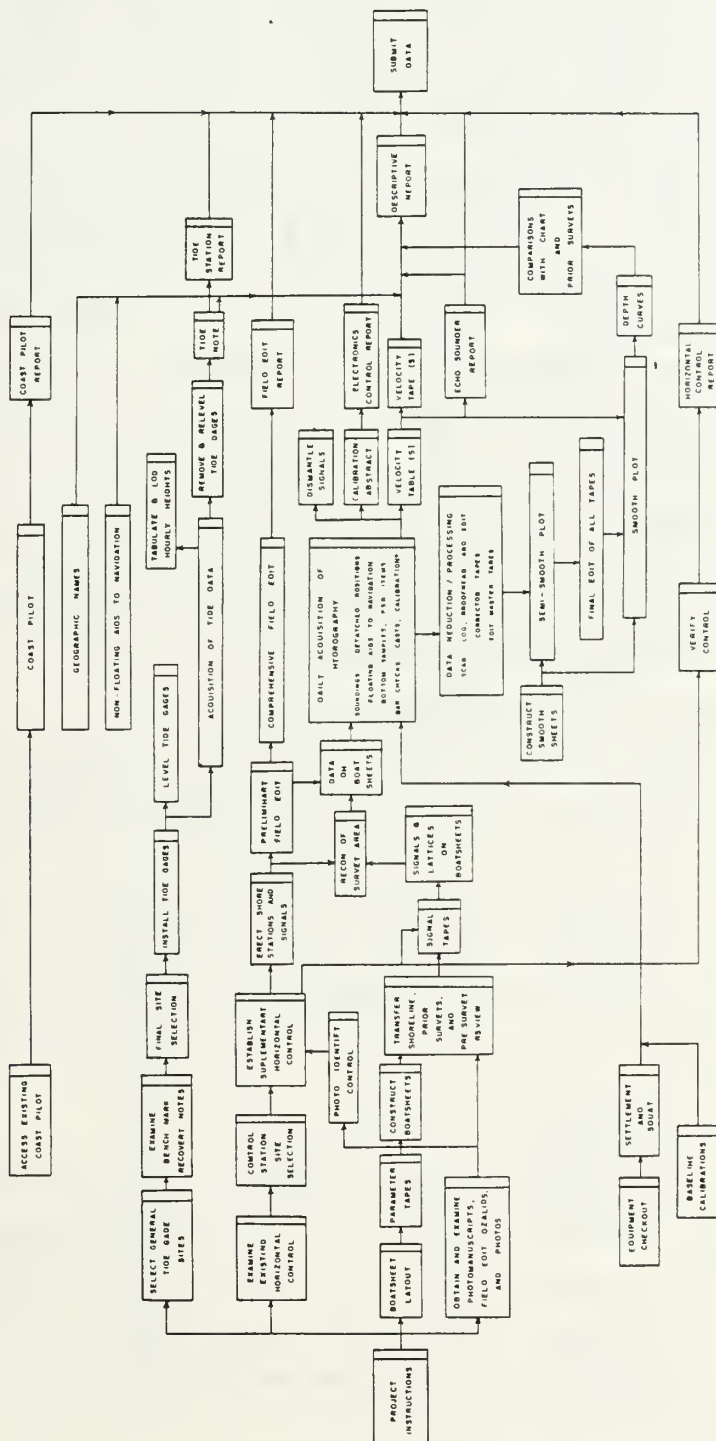


Figure 4.2 Hydrographic Survey Flow Chart

c. Data Processing Branch

The Data Processing Branch receives all the survey data, the Coast Pilot report, and the Descriptive Report upon completion of the field survey. This branch is responsible for all forms of verification with some performed directly by personnel in the branch. In the case of tide and geodetic information, the branch acts as a disseminator sending the material to the appropriate area of expertise for verification. The actual tide data received from the Tides Section are in the form of tidal correctors and tidal zoning information to be applied to the raw sounding values. The geodetic information is returned fully adjusted and reduced with field-generated control positions verified and geographic positions determined. The Coast Pilot report, if generated from the survey, is sent back to the appropriate section for review with deficiencies reported; a new printing of the Coast Pilot will then take place if deemed appropriate.

After all data are returned to the verification center, the branch performs the full reduction of position and sounding data and makes a full inspection of all material as the processing proceeds. Additions are also made as appropriate to the Descriptive Report. A National Ocean Service office data processing flow chart (Fig. 4.3) illustrates work flow in the Data Processing Branch.

d. Data Archives Branch

Two different sections of data archives should be maintained. One will act as the permanent data file, retaining all original survey data and related tide and geodetic information. File negatives generated by the Chart Compilation Branch will be in permanent storage here as

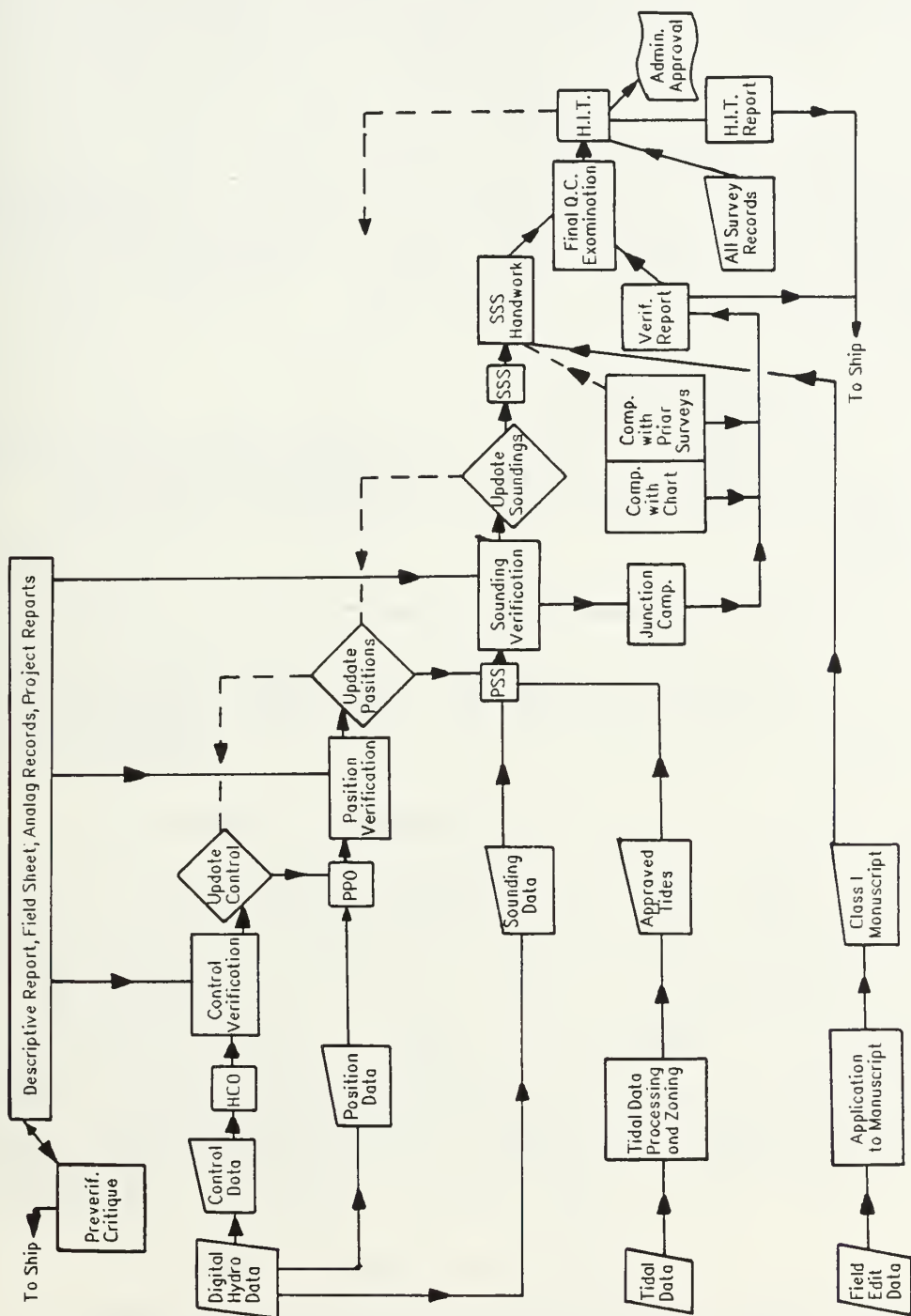


Figure 4.3 Office Data Processing Flow Chart

well. The other section will contain material necessary to continue with present chart production. This material includes the final smooth sheet and the Descriptive Report, both released to the Chart Compilation Branch on a temporary basis. Minimal staff is required to maintain this branch. Initially, one person, being well organized with good secretarial and research skills, will be fully able to perform the functions of the archives. Later on, as a series of continual chart products are being co-generated, additional staff might be required when deemed necessary by the organization.

2. Charting Division

The Charting Division performs functions related to all aspects of charting and is subdivided into four branches.

a. Chart Planning Branch

The Chart Planning Branch performs the first functions in chart production. The basic responsibility is the determination of survey and chart needs with an on-going review regarding update requirements. Planners are charged with performing overall assignment scheduling tasks necessary to insure full, cost-effective utilization of resources after priorities have been established. The full set of chart requirements are forwarded to the Hydrographic Division for subsequent individual scheduling based on the Chart Planning Branch overall scheduling scheme.⁷ Inputs to the branch could come in the form of deficiencies reported in the Coast Pilot necessitating a reprint. Additional

⁷Work flow, after initially being in the Charting Division, Chart Planning Branch, will remain in the Hydrographic Division through the archiving of the survey data. From that point until final distribution, all remaining work will be in the Charting Division.

inputs could include the identification of new needs, information related to prior surveys not meeting requirements (i.e., in quality or area surveyed), or deficiencies in Notice to Mariners regarding shoals and obstructions.

b. Chart Compilation Branch

At the conclusion of work flow in the Hydrographic Division, the smooth sheet and Descriptive Report are forwarded to the Chart Compilation Branch from the Data Archives. Cartographers are required to prepare a nautical chart compilation from which color separation can then begin. The end results of this process are a full set of reproduction negatives from which a final print can be made and the precursor file negatives which are forwarded to the archives for permanent retention. Quality control is essential in this branch to insure that the original survey "integrity" is maintained. Representation of bottom features should remain intact and critical defects should be identified which were not located by previous investigations.

c. Chart Printing Branch

The Chart Printing Branch produces the final nautical chart product from reproduction negatives furnished by the Compilation Branch. Again, a quality control function is performed. A random sampling of charts is done to insure a continuity in product accuracy. It eliminates the possibility of printing massive quantities of charts having a critical defect due to a problem with the printing press itself.

d. Chart Distribution Branch

The primary activity of the branch is the distribution of the final nautical chart product.

A graphical representation of the work flow sequence for the organization's two divisions would be particularly useful. Work flow is shown for year-round surveying capability (Fig. 4.5) and time based on seasonal surveying capability (Fig. 4.4), both assuming normal priority. Time estimates are subject to alteration with changing priorities of a particular chart product and also related to the number of employees utilized to perform a specific function at any point in the work sequence.

C. ESTABLISHMENT OF A MINIMUM SERVICE

The establishment of a minimum service as outlined in this thesis assumes no present hydrographic organization or capability exists. In most cases, the first priority will be conducting surveys of harbors and their associated approaches and channels to produce an accurate chart product capable of providing safe navigation for today's size ships. The first step after plans for hydrographic agency establishment have been approved is to immediately begin working on objectives necessary to fulfill the agency mission.

1. Alternative Survey Operation Methods

A critical decision must be made initially regarding the size of the unit expected to perform hydrographic field survey operations. To relate various operating units, data from the Pacific Marine Center (PMC) of NOS have been compiled using actual 1984 operational expenditures (Table IV). The operating units being compared are ship RAINIER (a 231-foot Class II vessel), ship DAVIDSON (a 175-foot Class III vessel), and the Pacific Hydro Party (a hydrographic field party).

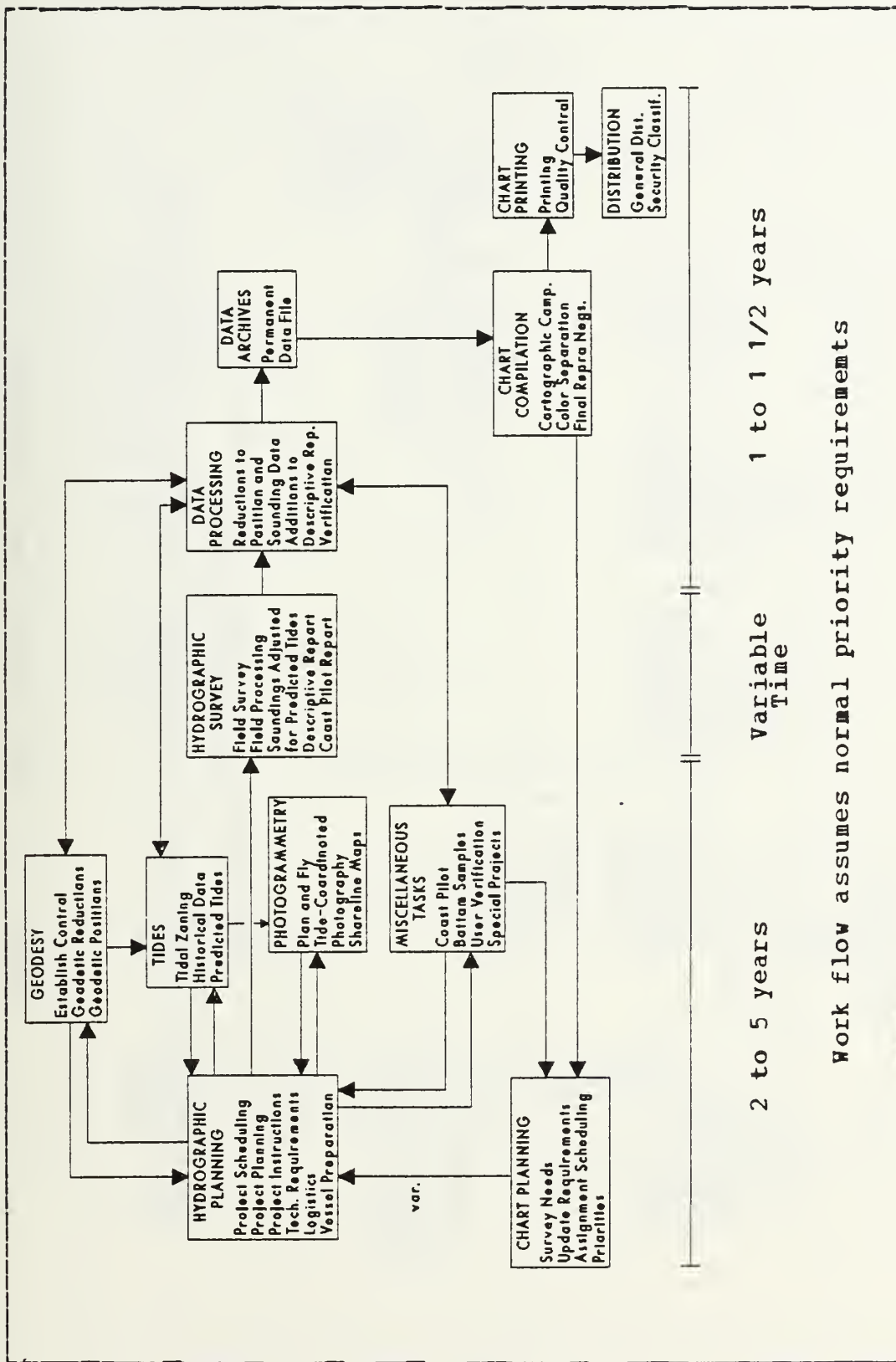
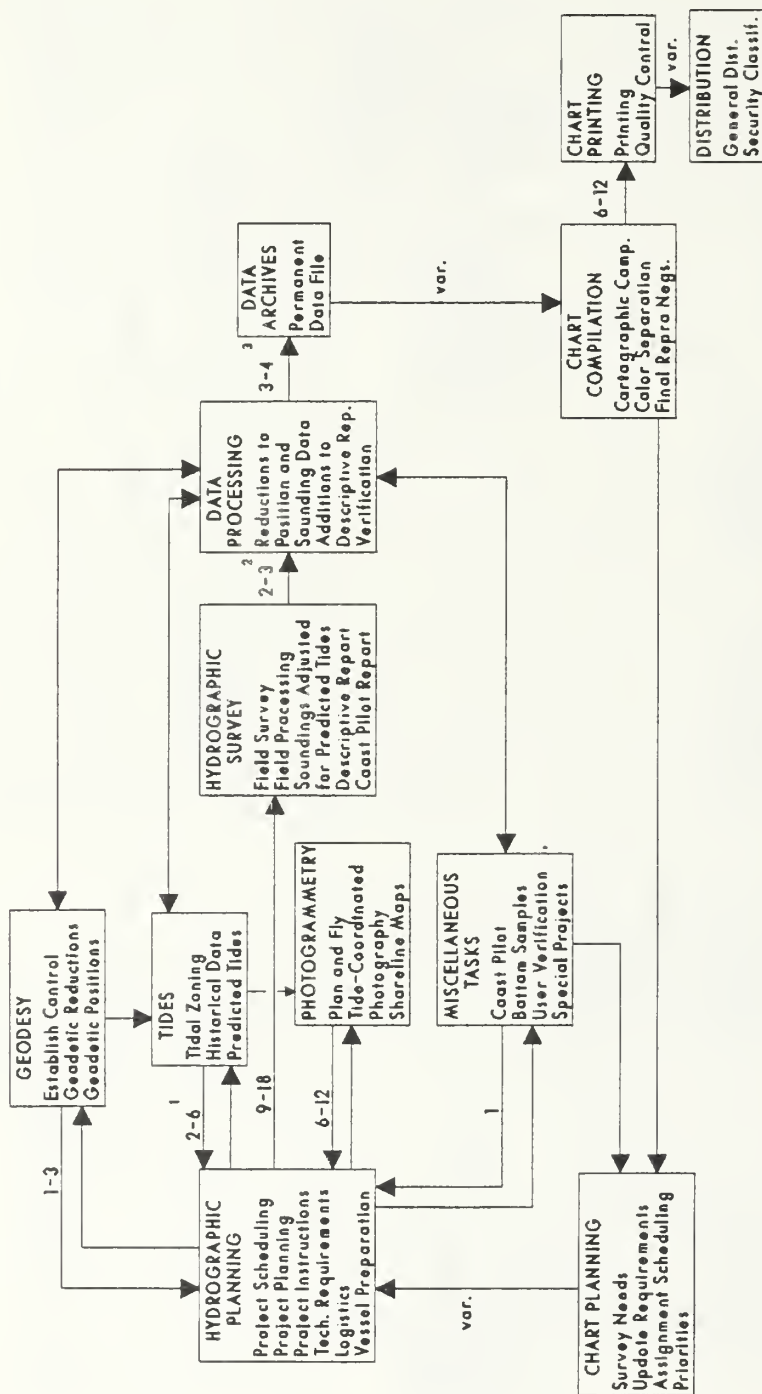


Figure 4.4 Seasonal Survey Operations



Work flow assumes normal priority requirements
All values are in months

¹Time increased if survey area devoid of historical tidal stations
²Add approx. 1 month for each additional survey in a given project
³Add approx. 1-2 months for each additional survey in a given project

Figure 4.5 Year-Round Survey Operations

TABLE IV
1984 PMC Survey Operation Costs

Operations Plans--FY 84
(\$1,000)

	<u>RAINIER</u>	<u>DAVIDSON</u>	<u>HYDRO PARTY</u>
Salaries	915.0	505.0	61.2 ¹
Other Compensation	431.6	216.1	9.8
Benefits	98.7	129.8	6.6
Travel ²	11.3	17.0	56.5
Transportation ³	4.4	6.0	1.6
Rent ⁴	45.9	20.5	6.0
Printing	0.8	0.0	1.3
Contract Services	28.3	22.0	10.0
Mess	109.0	53.5	0.0
Fuel	270.0	190.0	0.0
Supplies	72.6	82.0	12.0
Equipment ⁵	21.1	2.8	0.0
TOTAL	2,008.7	1,244.7	165.0

POSITIONS:

Commissioned Officers	9	8	2
Permanent	42	23	3
Temporary	18	12	1

Maintenance Plan--FY 84
(\$1,000)

	<u>Electrical</u> <u>Maintenance</u>	<u>Vessel</u> <u>Repairs</u>	<u>Total</u>
RAINIER	158.0	210.0	368.0
DAVIDSON	36.0	253.0	289.0
HYDRO PARTY	5.0	4.0	9.0

- ¹ Salaries include only Commissioned Officers
² Includes meetings and/or per diem
³ Transportation costs due to shipment
⁴ Xerox, telephone, helicopter, trailer space, etc.
⁵ Includes new ship items

Close examination of these operating costs illustrates the dramatic difference between ship and field party expenditures--it is a full order of magnitude. In a nation attempting to start a new hydrographic agency, consideration of this cost differential becomes an important factor.

In the initial stages, it is foreseen that necessary surveying work could be achieved with a small hydrographic field party consisting of six personnel. Slight variations may be required depending on the method of data acquisition. The usual field party equipment will consist of a covered survey launch for data acquisition, one or two smaller workboats for establishing and checking control and tending tide gages, an office trailer, and two vehicles. For the field party to function effectively, the personnel need to be able to perform (1) supervision of survey processing, daily review, administration, supply, and maintenance (Party Chief); (2) supervision of data acquisition (Assistant Party Chief); (3) maintenance of electronic and electrical equipment; (4) geodetic surveying; (5) drafting skills; (6) report writing; (7) tide station construction and maintenance; (8) diving expertise; (9) boat-handling experience; and (10) seamanship skills.

The above functions are broken down into approximate percentages of total field party time as follows: 20 percent geodetic, 30 percent survey launch data acquisition, 30 percent processing and report writing, and 20 percent administrative.

One important ingredient to a successful field party is the interdisciplinary skills associated with the various personnel. Such an approach is considered absolutely essential. It would be unacceptable and counterproductive if each member was only knowledgeable in one aspect or area of expertise. As a field party, based locally in the survey area with its own facilities often far from office support,

many things can occur which could hamper survey operations. Examples include equipment breakdown, decreased personnel strength due to illness, or a change in weather. With an interdisciplinary approach these temporary inadequacies could be alleviated by a transfer of responsibility, provided that the expertise is available on site.

The field unit will typically be involved in data acquisition, data processing, and tide station maintenance. All processing of data is done on site in office trailers which make up the primary logistic support facility for the field party.

In the determination of the capability of a particular method of survey operation, estimates have been developed by the Nautical Charting Division of NOS regarding the number of linear nautical miles (LNM) each type of operation is able to perform. A Class II or Class III ship completes 1000 to 2000 LNM of ship hydrography per month, while launch hydrography for a Class II and Class III ship complete 500 to 750 LNM and 250 to 500 LNM per month, respectively. This is in contrast to the hydrographic field party which completes 50 to 500 LNM of launch hydrography per month. The range of values has been based on the number and difficulty of the tasks performed other than running main-scheme hydrography. [Ref. 22, p. 9]

2. Start-Up Requirements

If manpower and funding deficiencies are encountered at the beginning when the organization is in its initial building stage, then logic dictates that the full organizational design previously described will itself take on the status of an objective over time. Instead, it has to be decided what bare necessities could be utilized immediately so that production could begin.

a. Restrictions on Size, Equipment and Manpower

The initial organization could function quite adequately with a very lean staff. The Canadian Hydrographic Service, Department of Fisheries and Oceans, has formulated a detailed proposal for the establishment of an Irish Hydrographic Service [Ref. 23] which discusses the personnel necessary to support a modest yet elite organization. The size of the agency in its beginning phases as originally perceived for this thesis is in basic agreement with the detailed Canadian Hydrographic Service study.

Several key assumptions have been made in regard to certain branch functions:

Cross-functioning at the planning level can be utilized if dictated by priorities, which means that management personnel in these positions will have appropriate backgrounds in both survey and chart planning.

Regardless as to what arrangements are made in vessel procurement (be it direct purchase of a new vessel, purchase and re-outfitting of an existing one, contracting out for a vessel on a when-needed basis, or a vessel supplied by the Navy on loan) the organization will need to rely on naval support for periodic maintenance and overhauling during the initial years.

Additional data processing and verification capability could be drawn from one of the other branches during periods of down-time. This branch will have the first priority in future hiring after the initial personnel have been employed.

Chart printing and distribution can initially be performed at the national topographic mapping facility printing center until such time as funds are available to establish a self-sufficient chart printing capability.

Twenty-three hydrographic personnel are deemed the minimum necessary to fully perform the primary organizational mission (Table V); these personnel must then be identified within the organization from the point of view of branch functioning (Table VI).⁸ The division heads will play key roles in the respective planning functions. The Secretary/Records Clerk will have a dual role temporarily. Initially this responsibility would be manageable by one person. Over time, as general work flow is increased, a permanent Data Archives person would need to be added.

TABLE V
Initial Personnel Organizational Requirements

Director	
1 Budget Specialist	
1 Secretary/Records Clerk	
Hydrographic Division (14)	Charting Division (6)
1 Supervisory Hydrographer	1 Supervisory Cartographer
1 Survey Planner	1 Chart Planner
1 Marine Specialist	1 Senior Cartographer
1 Geodesist	2 Cartographers
1 Tides Specialist	1 Photographic Specialist
1 Photogrammetrist	
1 Sr. Hydrog./Hydrographer	
1 Chief/Sr. Survey Technician	
2 Survey Technicians	
1 Asst. Survey Technician	
1 Electronic Technician	
1 Able Bodied Seaman/Mechanic	
1 Processing/Verif. Spec.	

⁸A listing of job titles and job descriptions for most lower level employees identified in this presentation can be found in Appendix A.

TABLE VI
Identification of Branch Personnel

Hydrographic Planning Branch
Supervisory Hydrographer
Survey Planner
Marine Specialist

Field Operations Branch
Geodesist and Asst. Survey Technician
Tides Specialist
Photogrammetrist
Sr. Hydrog./Hydrographer, Chief/Sr. Survey Tech.,
2 Survey Technicians, Electronic Technician,
Able Bodied Seaman/Mechanic

Data Processing Branch
Processing/Verification Spec.

Data Archives Branch
Secretary/Records Clerk

Chart Planning Branch
Supervisory Cartographer
Chart Planner

Chart Compilation Branch
Senior Cartographer
2 Cartographers
Photographic Specialist

Starting a hydrographic service with only basic equipment and a relatively small vessel is advisable. The basic equipment could consist of sextants and theodolites, these being the minimum needed to obtain a position fix. The limiting factor with either method is visual line of sight, which itself is a function of the height of the land, the visual range capability of a particular observer and time of day. The two main advantages of such simple surveying methods are that training in use of the equipment is brief and the costs involved in procurement are significantly lower than electronic position-fixing equipment. However, it is appropriate to note that not all kinds of electronic position-fixing equipment are cost prohibitive.

In fact, most nations today do rely on some form of electronic ranging capability, especially range/range microwave systems (3 to 10 GHz) within line-of-sight and medium-frequency systems (1 to 5 MHz) capable of extended over-the-horizon positioning. The use of an electronic position-fixing system allows for a reduction in the number of people which would be required when using a visual position-fixing system. The related maintenance support needed to keep the electronic equipment functioning properly would require additional electronic technician expertise available on site. The appropriate balance would be determined by the Director with input from the Marine Specialist and ultimately would depend on available personnel support versus funding capability.⁹ There are numerous tradeoffs which have to be considered when formulating the survey field party. Decisions in this regard will need to be made by the Director and the planning staff after all the alternatives have been investigated.

The determination of a particular type of hydrographic survey vessel depends on whether the vessel is to be engaged predominantly in basic charting activities or oceanographic research. Furthermore, basic charting activities can vary; this has a direct impact on the type and size of vessel required. A ship would be needed in deep ocean areas or areas well offshore, whereas a launch would be most adequate and likely more responsive for the majority of data acquisition in nearshore locations. The smaller boats would have the capacity to survey in shoal areas due to shallow draft and in locations inside harbors where maneuvering and surveying alongside a wharf or amongst anchorage buoys could prove hazardous and difficult for a larger vessel.

⁹For a complete listing of electronic position-fixing equipment available see Ref. 24.

Vessel determinations will allow the planners to choose a vessel having the required capabilities in size, range, endurance and speed. Dyde and Uhlig [Ref. 25, p. 92-93] offer some guidelines in attempting to arrive at the appropriate capability of a vessel. They recommend translating a customer's data requirement into a specific hydrographic or oceanographic task and then approximating this task to a corresponding number of operating surveying years or other appropriate unit of time. Their presentation identifies four physical parameters which have special importance in deciding on the type and size of vessel required, including prevailing weather and sea conditions, available manpower and associated experience, available shore support, and the size of the operational area. They also stress that the interdependence of several of these factors could cause conflicting requirements. For example, a large operating area and heavy seas over an extended period would imply a larger vessel, but a large area with limited shore support might yield greater survey effectiveness with a smaller vessel.¹⁰ Analysis of all factors enables one to judge the cost-effectiveness of the proposal and the associated vessel required to perform the necessary functions.

There will be situations where those charged with setting up the organization will find it more advantageous to go with a larger vessel. For example, the Navy of a particular nation might have a vessel which could be outfitted for hydrographic work with minimal cost outlays or priorities might dictate that a larger vessel be employed. In cases where a larger vessel is to be used, personnel and equipment would have to be increased with accompanying increases in overall maintenance expenditures.

¹⁰For a detailed description as to how these physical parameters interact and specific recommendations made for different situations, a further investigation of pp. 93-95 in Ref. 25 is advised.

The individual specifics for the case of a larger vessel will not be developed in-depth, but a study performed by the NOS Planning Staff entitled "Analysis of CY 1983 Hydrographic Survey Projects" points out basic differences in the three types of capabilities presently in use by NOS. For ease in presentation of comparisons on an order of magnitude basis of the highly detailed NOS Planning Staff Report, West Coast and East Coast operations for each type of operating unit have been averaged with one value for each type listed (Table VII).¹¹ Items pertinent to this NOS analysis are listed below:

Class II ships carry four automated hydrographic survey launches, four open boats, and 68 personnel.

Class III ships carry two automated survey launches, two or three open boats, and 36 personnel.

Hydrographic field parties in this study consisted of a launch, two small boats, an office trailer, two to three vehicles, and five to seven employees.

Operating expenses (salaries, personnel benefits, fuel, repairs, supplies, etc.) and depreciation of capital equipment illustrate a cost index based on the operation of field units on a daily basis.

The cost for ships was computed based on a 5-year average (1978 to 1982).

The costs used in the analysis to derive averages were actual expenditures and not adjusted for inflation.

Cost values represent a "cost index" used in making comparisons between the different operating units, and do not represent actual costs in 1983 dollars. These cost index values represent an average cost over several years.

Survey equipment requirements will vary depending on the needs of both an individual country and the particular survey involved. Certain types of equipment are considered standard for a minimum hydrographic service and should be carried aboard the survey vessel (Table VIII).

¹¹The data listed in Table VII contains information extracted from Attachment I of the NOS analysis [Ref. 22, pp. 8-9].

TABLE VII
Summary of NOS Cost Estimates

Yearly Costs (\$1,000)

<u>Operating</u> <u>Unit</u>	<u>Operating</u> <u>Costs</u>	<u>Deprec.</u>	<u>Total</u>	<u>Sea</u> <u>Days</u>	<u>Cost per</u> <u>Sea Day</u>
Class II Ship	2554	273	2827	191	14.8
Class III Ship	1401	186	1588	194	8.2
Hydro Field Party	227	12	239	240	1.0

b. Estimation of Space Requirements

Space requirements have been developed which conform to the proposed minimum organization already specified (Table IX). Note that these requirements represent neither berthing facilities which must be made available nor storage facilities necessary for the field equipment. Such factors will have to be considered on an individual basis depending on the vessel used and amount of field equipment to be housed in storage. In addition, chart printing capacity has not been included since this capability will come later after the organization has been operational for a period of time.

D. AUTOMATED HYDROGRAPHIC SURVEYING OPTIONS

If all the survey work is initially to be done in harbors, channels, or other areas within optical line-of-sight from shore as the primary organizational objective, choices are available in allocation of funds. Strictly

TABLE VIII
Basic Equipment Required For Survey

Survey Equipment

Survey Launch
Workboats
Electronic Position-Fixing System
Electronic Distance Measuring Instrument
Sextants
3-Arm Protractors
Odyssey Protractors
Theodolites
Levels and Level Rods
Tide Gages
Echo Sounder and Bar Check Apparatus
Automatic Data Recording Equipment or Sounding Volumes
Sounding Clock
Lead Line
Towed Dual-Channel Side Scan Sonar System
Bottom Sampler
Portable Radio Communication Equipment

Supplementary Equipment and Supplies

Signal-Building Material
CTD or STD Equipment
Winch Device
Wire Sweeping Gear
Meter Bar
Straight Edge
Sounding Pole
Survey Lights
Survey Tapes
Station Disks
Shovels
Cement
Other Miscellaneous Field Equipment
Full Compliment of Necessary Standardized Forms
Tape, Paper, Related Supplies (pens, pencils, etc.)
Drafting and Plotting Instruments

manual methods such as three-point sextant fixes or azimuth/azimuth positioning with a theodolite could be used. Either of the two modes are preferred if funds needed to purchase electronic positioning equipment are in short supply, if the geometry of the area is satisfactory, and if manpower capacity is available to support such operations. A full crew compliment is essential at all times when performing a

TABLE IX
Space Estimates

All areas are ft²

<u>Offices</u>	
Director	300
Division Head	200
Division Head	200
Secretary/Records Clerk	100
<u>Miscellaneous</u>	
Hydrographic Division	1200
Chart Planning Branch	400
Cartographic Work Area	1000
Electronic Work Area	300
Photographic Work Area	600
Admin. Files/Tech. Records	400
Conference Room	500
Rest Rccms (2)	200

5400 ft ² Total	

survey that utilizes visual positioning. In contrast, if funds are readily available and manpower happens to be the limiting factor, it would be advantageous to utilize some degree of automation in securing position fixes. The reason is that any degree of automatic requires less personnel in survey data acquisition. However, in situations of equipment failure with this scenario it must be assured that expedient repair could be accomplished so as not to indefinitely hamper survey operations.

There are situations which could dictate some degree of automation regarding data acquisition, data processing, or data dissemination even in initial stages of agency formation. The Australian experience is an excellent example of such a situation. The Royal Australian Navy Hydrographic Service concedes that its size in relation to its large area of responsibility has placed a strain on the traditional

methods of data acquisition and processing. Lacking the capacity to absorb large expenditures in research, the Australians have utilized the present technology of system suppliers and have embarked on a program of practical automation.

With a shortage of manpower, nations with charting requirements covering very large areas have a definite problem. Systems are available which interface depth and electronic position fixes, both correlated with time. Together with supplemental inputs (i.e., tide correctors) on an appropriate medium such as magnetic or paper tape, depth and position can be fully integrated on-board in real time and electronically plotted. Further sophistication can achieve sounding schemes based on a system of parallel straight lines rather than arcs about some electronic ranging system signal. The most recent technologies allow for information to be programmed in a way so that if a particular sounding falls outside certain range limits based on previous soundings, it would be rejected as bad data. Likewise, electronic position fixes can be similarly programmed whereby given a starting grid position, speed, direction, and preset time interval between fixes, a computer can determine if a particular position fix based on range rates is indeed accurate or if the position needs to be discarded. Depth or position information can be programmed to average a particular number of readings to yield one value which can then be recorded. Computer smoothing of the depth and position data is also possible.

Automation is also used in both field data processing and subsequent office data processing, although the problem of logging potentially bad data has not been totally resolved.

Regardless as to what degree of automation is used, certain conditions are apparent when automation is involved.

User employees need to have a reasonable amount of experience in computer programming and computer operations. More expertise must be available in electronic maintenance and repair; thus one full-time electronic technician proposed previously when automation wasn't considered would probably be insufficient if automation were to be utilized.

Any decisions to employ computer-assisted techniques in hydrography must be carefully considered. The personnel involved in the planning of such systems must take into account user satisfaction, user acceptance and system reliability. There are many questions which must be posed after the decision has been made to utilize a shipboard automated system. Selection of the appropriate system will depend on the answers to these questions. Weeks [Ref. 26, pp. 30-37] has developed an excellent set of questions that any prospective user should pose to a manufacturer before final selection of the shipboard automated system is made. A partial listing of Weeks' questions deemed critical follows:

General

Are soundings drawn online or offline?

What are the limits of speed and scale at which the system can be used?

What are personnel requirements, specifying both number and skill level?

What outputs are provided by the system?

What is the recommended method of maintenance?

What is the language of operation and maintenance?

What warranty is provided and what is the cost?

Hardware

What type of computer is used?

How much memory is supplied and how much memory can the computer accept?

What are the standard peripherals?

What is the power consumption?

Is protection against shock and vibration provided and/or necessary?

Software

What programming language is used?

What operating system is used?

What provision is made for the user to modify the programs?

How many decimal digits of accuracy are provided?

What high level languages are available for user programming with and without additional hardware?

Position Processing

How many position inputs can be processed simultaneously?

What smoothing or filtering can be applied to the raw data?

When data is smoothed is the raw data recorded?

What is the procedure for correlating positions and other data, and for correcting any time delays between measurement and acceptance by the computer?

Do position computations use spheroidal, spherical, or plane geometry?

What projections are acceptable?

Is any indication given to helmsman of distance along track?

What assistance is provided in maintaining whole lane count of 2-MHz positioning systems?

Can errors in positioning inputs or in position data be corrected online? Can they be corrected offline?

Depth Processing

If 600 depths per minute are available from the sounder, how many are processed or recorded as maximum, average, and minimum?

Is depth selection performed online or offline?

What is the method used for rejecting false echoes?

What method is used to select soundings?

How are tide correctors applied?

What provision is made for correcting depth sounder errors?

Is there any provision to correct for the vertical motion of the vessel?

Chart Preparation

What are the limits of chart size, chart scale, and chart orientation?

What annotation is provided?

Can points or lines be preplotted by their coordinates?

What size figures are used to plot soundings?

What is the location of a sounding shown by a group of digits?

How are decimal values shown?

What means are provided to correct for distortion of the plotter paper?

Accuracy

What means are provided to relate the final chart to the raw data, so that soundings may be checked?

What is the accuracy in computing an xy position?

How has manufacturer determined accuracies--are they based on theoretical considerations or actual field trials?

What accuracy of depth selection is warranted by the manufacturer with respect to frequency of bad soundings and standard deviation of the remaining soundings?

Additional Features

What is the procedure to be followed to delete, amend, or insert soundings on the output tapes?

What features will help to detect or prevent operator error?

What features provide greater convenience for the operator?

What are the means for checking correct hardware operation?

By obtaining answers to these questions, a carefully calculated decision can then be made as to which system would be most appropriate under a given set of circumstances.

E. HYDROGRAPHIC AGENCY BUDGET ESTIMATES

Very specific criteria need to be set to before formulating an organizational budget. In the organization proposed in this thesis, the key elements affecting all cost outlays are based on the following:

Initially, there will be 23 employees in the organization.

All survey operations and related field work will be accomplished with one 29-foot launch and two smaller workboats. The survey launch used in this analysis is an aluminum hull Jensen. The workboats consist of one 16-foot Boston Whaler and one 17-foot Monark. The Whaler will be a field operations support boat used to tend tide gages and make beach landings when necessary. It performs better in areas of sea action or open ocean. Conversely, the Monark offers a stable platform and will be used as a hydrographic workboat for data acquisition in harbor areas where space or depth limitations would discourage use of the deeper draft Jensen launch.

There will be only one hydrographic field party available to perform surveys.

The survey launch will be both covered and large enough to accommodate any electronic equipment which might go on board.

If the agency sees a need for a larger survey vessel, it would take anywhere from 2 to 4 years to acquire and outfit. All equipment, personnel, and maintenance costs would then need to be adjusted. Appropriate vessel size is something the agency planners need to evaluate carefully.

Photographic requirements generating color proofs, file negatives, and reproduction negatives should utilize the most up-to-date technology. This technology

includes the new daylight working-type film which needs a 1000-watt quartz light and requires only subdued lighting in the photographic area. Such film has a lower silver content and therefore lower costs per roll. A processor is needed which is capable of handling the appropriate sized negatives used to make the nautical chart. Additional photographic equipment includes a film cutter, shop microscope and densitometer, manual punch for registration of material, a vertical camera, and a vacuum frame with pump and exposing light. It is suggested that rub-ons be used to generate color proofs required in quality control since this process is by far the cheaper alternative.

Silver recovery of discarded negatives should be practiced at all times to reduce costs.

To ascertain what estimated costs would be incurred in setting up the hydrographic organization, it is first necessary to itemize the personnel and equipment needed in the first 3 years of agency formation (Tables X, XI and XII).

It is clear that the hydrographic field party has the lowest daily costs (see Table VII), and combined with the data using actual 1984 costs (Table IV) illustrates that in most situations a hydrographic field party would be the preferred mode for survey operations. These data also show that launch hydrography is the most practical when financial constraints weigh heavily in decisions regarding survey operations. Previous discussion pointed out that launch hydrography requires the least amount of personnel which is another key factor in determining the survey mode most applicable to a country's situation. For these reasons, all budgetary estimates to follow will consider the launch-equipped field party as the means by which operational costs have been determined. For a scenario utilizing a larger vessel, it will be easy to extract the necessary values and

TABLE X
Year One--Personnel and Equipment

<u>Personnel Hired</u>	<u>Equipment Purchased</u>
1 Director ¹	1 26-ft Jensen Launch w/ hull-mounted transducer
1 Budget Specialist	1 Office Trailer
1 Marine Specialist	1 16-ft Boston Whaler
1 Super. Hydrographer	1 17-ft Monark with hull-mounted transducer
1 Super. Cartographer	1 Short Range Electronic Positioning System
1 Tides Specialist	1 Level & Level Rod
1 Secretary	1 Automobile
<u>Office Equipment</u>	6 Sextants
Desks & Chairs	2 Theodolites
Filing Cabinets	4 Radios
Drafting Tables	4 Bubbler/ADR Tide Gages
Drafting Equipment	2 Handheld Calculators
Misc. Supplies	
Photocopy Machine	

¹ The director should be hired immediately.

perform proper substitutions to obtain the appropriate costs.

A summary of costs which would be incurred by the agency in start-up (Table XIII) assumes the purchase of one 29-foot Jensen survey launch, one 16-foot Boston Whaler, and one 17-foot Monark for survey operations. A substitute for the Jensen launch or any additional vessel appropriation will require changes in the proposed budget figures.¹²

¹²A detailed itemization of costs can be found in Appendix B.

TABLE XI

Year Two--Personnel and Equipment

<u>Personnel Hired</u>	<u>Equipment Purchased</u>
1 Geodesist	1 Survey Echo Sounder
1 Photogrammetrist	1 Portable Echo Sounder
1 Survey Planner	1 Laser EDM
1 Chart Planner	1 Medium Range Elec.
1 Chief/Sr. Survey Tech	Positioning System
1 Sr. Hydrographer	1 4-Wheel Drive Truck
1 Sr. Cartographer	1 Sound Velocity Sensor
1 Electronic Tech	Misc. Survey Equipment
1 ABS/Mechanic	
2 Survey Techs	

Office Equipment

Desks & Chairs
 Drafting Tables
 Drafting Equipment
 1 Office Safe
 2 Flat Files

TABLE XII

Year Three--Personnel and Equipment

<u>Personnel Hired</u>	<u>Equipment Purchased</u>
1 Survey Tech	Diving Support Equipment
2 Cartographers	1 Current Meter
1 Photographic Spec.	1 Side Scan Sonar System
1 Processing Spec.	

Office Equipment

Desks & Chairs
 Drafting Tables
 Drafting Equipment
 Personal Computer
 Photographic Equipment
 Darkroom Equipment

TABLE XIII
Summary of Expenditures

	(\$1,000)				
Year	1	2	3	4	5
Oper. Costs	242	611	753	748	748
Capital Costs	295	281	120	20	20

V. TRAINING REQUIREMENTS & TECHNICAL ASSISTANCE

Hydrography embraces a wide ranging and diverse set of scientific disciplines. These include geodesy, photogrammetry, hydrographic surveying, nautical science, and cartography. Special knowledge is also required in the following areas: Electronic equipment use and methodology; mathematical error analysis and measurement adjustment; management expertise and administrative skills; establishment and conduction of training programs for lower level employees; and strategic planning capabilities. It is unlikely that any one person would be well-versed in all these topics.

A. TRAINING

Upper level employees in the newly established agency should be hired as early as is possible without sacrificing quality. An in-depth search for these personnel will be needed to find those that are highly qualified, especially in a field such as hydrography where there is a definite lack of available and experienced people in the pool from which to draw. Recruitment could prove extremely difficult--possibly the most difficult task the agency might ever perform. There should not be any apparent weaknesses in abilities when recruiting the positions of Director, Marine and Budget Specialists, Survey and Chart Planners, and the Supervisory Hydrographer and Cartographer. All need to be highly trained specialists in their respective fields with a broad background in related areas covering the full hydrographic spectrum. They should also be capable of extended periods of independent work without supervision and have enough knowledge to oversee and participate in in-house training programs within each realm of expertise.

1. Required Training for Lower Level Employees

When recruiting lower level employees training becomes critical, both immediately after they are hired and later on as the organization progresses from its initial stages. One cannot expect to train lower level personnel with differing expertise and backgrounds within the confines of a single training program, yet there are some areas that all employees should be trained in as a mandatory requirement. A course spanning approximately 10 weeks in Nautical Science similar to the one given to NOAA Corps Officers at the Kings Point Merchant Marine Academy falls under this category. That course gives all new officers the necessary exposure in all aspects related to navigation, seamanship, and rules and procedures as they relate to the mariner. A course like that one would give all employees a real feel for just what the chart product is used for and would illustrate the importance of a product that is accurate, easy to read and understand, and one that clearly portrays the nature of the bottom topography.

All personnel should also have training exposure related to practical aspects of survey operations, spanning 6 to 10 weeks and include a balance between classroom instruction, laboratory exercises, and field procedures. Finally, they should be required to undertake training in basic cartographic procedures and principles to improve drafting abilities and gain a basic understanding in the production of the primary product, the nautical chart. A basic cartographic course could be condensed into 4 or 6 weeks for all those not initially hired as cartographers with additional training of approximately 6 weeks for the required cartographic specialist expertise.

The total mandatory training time thus required will range from 20 to 26 weeks in duration. All three of these

initial training courses (Table XIV) hopefully could be accomplished within the borders of the individual nation as an in-house operation. The Nautical Science training could be integrated with the Navy at a Navy facility. The Marine Cartographic training could easily be accomplished with only

TABLE XIV
Required Training For Lower Level Personnel

Nautical Science

Coastal Navigation and Piloting
Celestial Navigation
Rules of the Road
Use of Radar and Radar Plotting
Small Boat Handling
Ship Stability
Seamanship
Nautical Terminology
Damage Control and Fire Fighting
Safety at Sea
First Aid
Communications and Radio Procedures
Law of the Sea

Field Survey Operations

Horizontal Control
Importance of the Field Sheet
Operation of Electronic Equipment
Positioning Methods
Operation of Visual Positioning Equipment
Combined Survey Operations
Hydrographic Survey Techniques
Survey Specifications
Shoreline Sounding Operations
Field Edit Procedures
Corrections to Soundings
Tides and Water Levels
Wire-Drag Operations
Technical Report Writing

Cartographic Training

Chart Compilation Techniques
Color Separation Techniques
Photo Lab Training
Cartographic Specifications and Procedures
Computer Digitizing/Plotting of Data (if applicable)

minor revisions to the syllabus at a national cartographic training center. The survey experience could begin as soon as the end of Year Two after the launch has been obtained and outfitted for survey operations. If the in-house training programs are not possible to coordinate, even these basic training courses are taught at numerous locations worldwide and could be accomplished with international cooperation. Ideally all mandatory training programs, irrespective of where they are held, should be completed by the end of Year Three.

Depending on the circumstances, there is a possibility that the management personnel might feel the need to include themselves in the mandatory training programs just described. Overriding factors might play a role in discouraging this prospect or at least delaying it until circumstances allow the liberty for these people to be away from production planning and operations for an extended period. However, it is important to note that any of the management personnel who intend to actively participate in one or more of the training programs as an instructor should conduct a thorough review of their particular realm of experience prior to the instruction.

2. Advanced Training

Further advanced training will be required for each of the different areas of expertise; such training could occur over time and be integrated in such a way as not to disrupt work flow to any significant degree. In time, cartographers should be trained in advanced geodetic and hydrographic surveying principles and techniques. Survey technicians and hydrographers should be trained in advanced cartographic methods and applications. Likewise, seamen and electronic technicians should be further trained in more advanced principles of geodesy and surveying. Advanced

training would eventually permit total interdependence between employees in the hydrographic survey party. It would also enable full cross-functioning to occur under all circumstances to keep survey work flowing in times of potential crisis due to temporary loss of critical personnel. In addition, personnel mobility would be an available option between the two production divisions in times of shifting priorities, placing cartographers in the field or surveyors in the office when deemed necessary and appropriate.

Any potential employee picked for advanced training, especially if it involves going abroad, must have the appropriate educational background to handle the advanced topics he or she will be expected to learn. The employee also must have the language skills necessary to comprehend and absorb the material being taught at the advanced learning center--otherwise the entire process might be a waste of time and money.

Depending on the circumstances, some nations might have a further requirement for training in automated techniques as applied to hydrographic data acquisition and/or digitization of cartographic information. Training in automated techniques would depend on whether these skills were necessary in a particular situation in the country involved. These skills would most likely not be needed immediately, but with rapidly changing technology and advantages that automation offers regarding increased production and decreased man-hours, this situation could change. As the prices for much of the electronic equipment presently on the market continue to decrease, automated capabilities are potentially within the financial reach of many nations not presently utilizing this technology. A result of any automated capability would be the need for increased training in computer operations and computer programming for some of the employees.

3. Training Programs Available Worldwide

The IHO, as one of its functions, will advise any nation with the name and address of the appropriate national contact who will aid in the arrangement of overseas training programs, accomplished by mutual consent between the developing country and the individual nation conducting a particular training program. A list of those nations which sponsor major training programs in surveying, mapping, and related areas (Table XV) has been extracted from conference papers [Ref. 2, pp.90-91] and [Ref. 27, pp. 342-349]. Included in this list is supplemental information relevant to the particular programs involved--non-availability of information is shown by a hyphen.

A noteworthy item regards training of personnel in the country establishing the hydrographic program by outsiders rather than the country sending their employees overseas to a foreign training center. An example of this type of program is the Hydrographic Survey Assistance Program (HYSAP) conducted by the U.S. Naval Oceanographic Office. The country receiving the training provides survey personnel, a survey vessel including fuel and crew, logistic support, and work space. The advantages to this approach are numerous:

It is easier to find a small number of qualified instructors conversant in a particular language than it is to teach a language to those who would attend training programs at different locations around the world.

Training people in an atmosphere and culture familiar to them is always more effective and fruitful. This includes utilizing the same equipment and vessel that will be the tools the trainees will be using after the training has ended and hydrographic work has begun.

TABLE XV

Major Training Programs in Surveying and Mapping

<u>Country</u>	<u>Category</u>	<u>Level</u>	<u>Duration</u>	<u>Language</u>
Argentina	Surveyor	Advanced	4 years	Spanish
Australia	Surveyor	Basic	1 year	English
Australia	Sur. Asst.	Bas./Adv.	12 weeks	"
Australia	Surveyor	Advanced	-	"
Austria	Surveyor	Advanced	-	En/Fr/Ger
Brazil	Sur. Asst.	Specialist	40 weeks	Portuguese
Brazil	Sur. Asst.	Intermed.	19 weeks	"
Brazil	Surveyor	Advanced	1 year	"
Canada	Surveyor	Advanced	12 weeks	English
Egypt	Surveyor	Advanced	2 years	-
Fed. Rep. of Germany	Surveyor	Advanced	1 year	German
Finland	Cartog.	Advanced	3 years	"
France	Surveyor	Advanced	3 years	-
France	Sur. Asst.	Basic	2 years	French
France	Sur. Asst.	Advanced	1 year	"
France	Surveyor	Advanced	2 years	"
Ghana	Sur. Asst.	Basic	3 years	-
Ghana	Surveyor	Advanced	2 years	-
Hungary	Surveyor	Advanced	2 years	-
India	Surveyor	Basic	16 weeks	English
India	Surveyor	Advanced	37 weeks	"
Israel	Surveyor	Advanced	3 years	Hebrew
Italy	Surveyor	Advanced	65 weeks	Italian
Ivory Coast	Sur. Asst.	Basic	-	-
Japan	Surveyor	Intermed.	26 weeks	English
Kenya	Surveyor	Basic	-	-
Malaysia	Cartog.	Basic	7 months	-
Netherlands	Photogram.	Advanced	8-18 mos	Eng/Fr
Netherlands	Cartog.	Advanced	1 year	"
Nigeria	Cartog.	Basic	-	Eng/Fr
Nigeria	Cartog.	Advanced	-	"
Norway	Cartog.	Basic	-	-
Philippines	Surveyor	Advanced	5 years	English
Poland	Cartog.	Advanced	3 years	-
Spain	Cartog.	Basic	2 years	Spanish
Spain	Surveyor	Advanced	3 years	"
Spain	Sur. Asst.	Basic	1 year	"
Sri Lanka	Sur. Asst.	Basic	-	-
Sudan	Photogram.	Basic	2 years	-
Switzerland	Photogram.	Advanced	18 mos	Eng/Fr/
Switzerland	Cartog.	-	4 years	Ger/Span
Turkey	Surveyor	Basic	1 year	Turkish
Turkey	Sur. Asst.	Basic	1 year	"
U.S.S.R.	Cartog.	Advanced	58 mos	Russian
U.K.	Surveyor	Bas./Adv.	10-24 wks	English
U.K.	Sur. Asst.	Bas./Adv.	8-14 wks	"
U.K.	Surveyor	Basic	5 weeks	"
U.K.	Surveyor	Advanced	6 mos+2 yr	"
U.S.A.	Surveyor	Advanced	2 years	English
U.S.A.	Surveyor	Advanced	1 year	"
U.S.A.	Surveyor	Advanced	48 weeks	"
U.S.A.	Surveyor	Basic	13 weeks	"

The students would feel more comfortable in their natural environment and therefore would be more receptive to learning.

The overall training costs and supplemental expenditures would be decreased dramatically. There would be a dramatic decline in travel expenditures, living expenses for food and lodging, and in the cost ratio of dollars per student-hour of training.

There will undoubtedly be circumstances unique to each nation. If the training is conducted at home, this unique situation would be recognized and thus could be dealt with in an appropriate manner. Examples include use of particular equipment items not ordinarily utilized which happen to be available requiring special instruction or the unusual aspects of the prospective survey areas which might dictate a unique approach that should be addressed. If the trainee were enrolled at a foreign training center, the individual attention required to utilize such special equipment would put too great a strain on the time and resources of the training program.

Many ideas and concepts represented by technical terminology are likely to be lost due to translation of the language if the student was enrolled at a foreign training center. Such a situation would not occur to as significant a degree if the training were conducted locally. This would be true if the training was performed by an individual who spoke the native tongue or if a translator, familiar with hydrographic terminology, was responsible for getting these ideas across to the students.

B. TECHNICAL ASSISTANCE

When one considers the limited resources of developing nations, any attempt to establish a national hydrographic agency would undoubtedly require some degree of technical assistance. There are many types of technical assistance available from a wide variety of international and national organizations. Assistance can be provided in various forms. Advisors are provided when needed to train personnel in the developing nations, equipment is supplied to support survey operations, and financial aid grants are used to supplement agency costs both at the time of agency establishment and later on for daily operations. Financial assistance can very often make the difference between success and failure of any organizational mission. Funds are often needed to lure the best and most qualified personnel into permanent employment and are equally crucial when monetary shortages can lead to a lack of necessary or suitable equipment. A summary of organizations follows, each with a brief description of its mission and objectives.

International Hydrographic Organization--Numerous kinds of technical assistance are available from the IHO. Its mission is to remain in the forefront in acting as the source of technical advice and as a coordinating body in promoting establishment or strengthening of hydrographic capabilities upon request by recipient countries. The IHO will arrange for experts from the International Hydrographic Bureau (IHO headquarters in Monaco) or Member States to visit developing countries upon request. The experts will assess existing facilities and needs, render advice in establishing or strengthening hydrographic capabilities, including guidance provided for the establishment of a hydrographic service, and provide advice in the formulation of projects. An inventory is maintained of all hydrographic

training courses offered worldwide. The IHO encourages and follows the development of bilateral arrangements between countries with well established hydrographic offices and those desiring establishment of hydrographic capabilities, and investigates the availability of funding from the international community.¹³

Intergovernmental Maritime Consultative Organization-- The Intergovernmental Maritime Consultative Organization is a specialized agency of the United Nations (U.N.) with a mission which is solely concerned with maritime affairs. The mission objectives include facilitating governmental cooperation on technical matters relating to shipping, safety at sea, and navigation.

Intergovernmental Oceanographic Commission-- The objective of the U.N. Intergovernmental Oceanographic Commission is to promote research in oceanographic processes, dynamics, and resources through governmental interaction.

Colombo Plan for Cooperative Economic and Social Development in Asia and the Pacific-- Founded in 1950 by the U.N. to promote the development of newly independent Asian member countries, the Colombo Plan for Cooperative Economic and Social Development in Asia and the Pacific presently has 26 member countries. Colombo Plan aid covers all forms of socio-economic development. Capital aid consists of grants and loans from six developed countries to the developing member countries of the Plan and technical assistance is provided through services of experts and technicians, training fellowships, equipment, travel fellowships, and funds for conferences, training and research.

¹³For a detailed description, see the International Hydrographic Bureau Special Publication 47 entitled Training and Technical Assistance in Hydrography.

Delegation of the Commission of the European Communities in the Pacific--Funds allocated under particular programs of the U.N., such as the Delegation of the Commission of the European Communities in the Pacific, are used to finance projects in areas of technical cooperation, especially in fields of training and technological adaptation or innovation. Capital projects related to rural development, industrialization, energy, mining and tourism, all of which could relate to hydrographic mission requirements, are also funded by the Commission.

Economic and Social Commission for Asia and the Pacific--The Economic and Social Commission for Asia and the Pacific (ESCAP), under the auspices of the U.N., initiates and participates in measures for facilitating concerted action for economic and social development. Recent hydrographic-related activities include development of shipping, ports, inland waterways, technology, international trade, and natural resources. ESCAP identifies common problems among member countries, facilitates international cooperation, allocates funds, provides training, extends technical assistance and advisory services, and acts as a disseminator of information.

ESCAP Regional Mineral Resources Development Center--The ESCAP Regional Mineral Resources Development Center organization objectives include providing technical assistance through a group of international specialists on mineral exploration and exploitation, an area of vital significance addressed by hydrography, in addition to bilateral or multilateral funding.

Institute of Marine Resources--Sponsored by the U.N., the Institute of Marine Resources carries out research in regional marine resources and offers funds to be used in training and development of educational programs. When fully established, its scope will include topics such as

marine geophysics and geology; physical and chemical oceanography and related maritime meteorology; ocean, coastal and environmental engineering; and marine and fisheries biology.

Several individual nations also offer various forms of technical assistance. The United States, through arrangement by the U.S. Naval Oceanographic Office and the Defense Mapping Agency under the auspices of the HYSAP program, provides on-the-job field survey assistance in a developing country. This includes technical assistance and advice, training, technical material, equipment loan, cartographic assistance, and liaison assistance.

New Zealand has been providing technical assistance and training in surveying and mapping to Pacific and Asian territories for over 25 years. The assistance ranges from the establishment of training centers outside New Zealand to providing personnel designated to work in the developing country to advance surveying and mapping capabilities. The latter assistance has declined in recent years since necessary skills are increasingly being acquired by local personnel.

The Federal Republic of Germany, in order to meet the demand of continued information exchange on technical matters by top-level managers and specialists, initiates the organization of workshops of 2 to 3 weeks duration at intervals of 2 to 4 years. Technical cooperation is also implemented in the form of technical assistance projects in surveying and mapping. These involve pilot projects dealing with instrumentation, on-the-job training, and technical cooperation in the establishment of educational facilities. Countries desiring technical assistance must initiate a request directly through the embassy of the Federal Republic of Germany in their country.

Many nations provide international cooperation in hydrographic surveying, primarily to promote safe navigation. As an example, a hydrographic survey was conducted along the Straits of Lombok and Makassar by Indonesian personnel in 1975 with the Japanese government providing necessary expenses for the survey including survey equipment, receivers, and some telecommunication equipment. Smooth operation of the sophisticated equipment was accomplished with Japan supplying the necessary technicians and the training of Indonesian operators. Previous to this, Indonesia, Japan, Malaysia, and Singapore conducted the Four Nation Joint Surveys of the Malacca and Singapore Straits, which lasted from 1968 to early 1975. [Ref. 28, p. 349] Similar programs have been initiated worldwide through international cooperation based on mutual interests of the nations involved.

VI. SUMMARY AND RECOMMENDATIONS

A. SYNOPSIS OF GUIDELINES

The guidelines outlined in this thesis have been based on a wide variety of assumptions. The introduction addressed assumptions regarding agency jurisdiction, personnel availability, and geodetic, topographic, and printing support capability. Other assumptions dealt with mission and objective priorities. All of these assumptions have influenced the cost estimates established to support the agency as proposed in these guidelines.

It was first necessary to investigate the need for accurate and up-to-date nautical charts by developing nations. After the need was identified, several factors were cited to justify hydrographic agency formation. Accuracy is presently demanded regarding safe navigation, increased maritime trade, military considerations, recreational activities, and rising local interests of developing nations. In many cases the users associated with these requirements are at present dissatisfied. They see a continued need for updated charts due to deeper draft vessels, the condition of prior surveys, and quality control methods utilized in the past which have occasionally led to nautical charts of questionable quality.

With this as background, the proposed organizational purpose, mission, objectives, and primary product were then identified. The production of nautical charts to ensure safe navigation was shown to be the primary mission, with the most immediate objective usually being the recharting of ports, harbors, and their approaches. Important aspects of the nautical chart were discussed, dealing with the identification and portrayal of necessary information and features crucial to the mariner.

The development of a hydrographic office is a progressive process as summarized below.

Overseer of Hydrographic Service

After examining several factors it was concluded that the civilian sector of government as overseer would be the most appropriate for those nations not presently having a hydrographic capability.

Organizational Structure and Function

The organization has been set up from an action perspective. Updated hydrographic surveys and nautical chart revisions are priorities. The agency design has been formulated in an attempt to limit bureaucracy and maximize both work flow and product output. With the needs as outlined, a small, highly skilled cadre of 23 employees are capable of fulfilling the mission in the near term. Personnel will be added later as management deems necessary.

The functional blocks of the organization follow this action orientation. Beginning with chart requirements, planning is done to set all criteria regarding alternatives in satisfying these requirements, including identification of priorities and scheduling. Priority items which require updated surveys are forwarded to the Hydrographic Division. Here, survey planners prepare written Project Plans and Project Instructions for each survey project. Peripheral information is also disseminated to the necessary field survey support functions (i.e., tides, photogrammetry, geodesy) as needed. The entire package is then assembled by the Hydrographic Planning Branch and forwarded to the field party personnel. The survey continues with daily checking of data and upon completion of the survey data acquisition, office verification and processing of the data begins. Dissemination again occurs, with tidal and field geodetic data sent off for specialized verification. The

adjustments are returned to the Data Processing Branch where a full quality control check is performed. The result yields a final smooth sheet of corrected and verified positions and soundings, which is then archived until chart compilation is to begin. Finally, the printed charts are distributed to accomplish the mission of the organization.

Start-Up Requirements

After investigation of possible alternatives, this thesis identified criteria needed to accomplish the mission of the hydrographic office. Although each topic has been fully discussed in the text, citation of appropriate tables and figures which represent particular ideas and concepts are included below as an aid to easy access of such information. Initial success was shown to be achievable with a total of 23 employees with a list of personnel (Table V) and accompanying functional breakdown (Table VI); full job descriptions for most lower level employees are detailed in Appendix A. Surveys would be performed with a hydrographic field party of six personnel utilizing a launch as the appropriate type of survey vessel. Basic equipment and space requirements are illustrated (Tables VIII and IX, respectively) and estimates have been diagrammed showing year-round surveying capability (Fig. 4.5) and seasonal survey operations (Fig. 4.4) as they relate to overall time requirements. Based on all the above, start-up scheduling has been formulated and identified for the first 3 years of agency establishment (Tables X, XI, and XII). A summary of estimated expenditures over both the near and intermediate terms is given (Table XIII) with a full breakdown of costs shown in Appendix B.

Training

Training was addressed on several levels. Topics dealing with initial training of lower level personnel have

been put forth (Table XIV), followed by investigation and discussion of advanced training needs over the longer term. Major worldwide training programs covering the full spectrum of surveying and mapping have also been identified (Table XV). In addition, a full range of national and international technical assistance programs have been outlined, each with its own summary of program objectives.

To get a better feel for what many developing nations see as problems in establishing or expanding hydrographic capability, a questionnaire was mailed to approximately 40 countries. Fifteen responses were received from around the world. Many items were identified, but some were more noteworthy based on the frequency of occurrence. The greatest problem identified was funding. The reasons for increased funding demands vary from the high costs associated with the purchase of modern survey equipment these nations deem necessary, to chart printing and cartographic digitizing equipment, to the purchase of new survey vessels needed to replace those presently in use but outdated by today's standards. Language problems were also commonly mentioned as an obstacle, especially in situations where a nation has sent a trainee overseas for advanced schooling. Lack of adequately trained and experienced personnel was frequently cited. Points expressed as general statements include an overwhelming number of responses stating that navigation safety is the highest priority objective and that most data acquisition and data processing are presently performed using manual processes. Both points were among the assumptions made earlier in this presentation. The 15 nations responding represent a global cross section of socio-economics, and it is highly likely that similar situations exist among most developing nations around the world today.

B. RECOMMENDATIONS

Existing hydrographic units within developing nations should make a stronger bid for funding support. Survey departments in most nations have made cadastral surveying the greatest priority, followed by topographic surveying, with hydrographic surveying coming a distant third as the lowest of priorities. In those nations where basic hydrographic work is performed by the military it can be very difficult to obtain increased funding for what is perceived as a non-military expenditure.

Developing nations should recognize the importance of retaining personnel, which increases the experience level of the agency and allows recovery of funding for training in advanced subjects. Adequate wages must be paid to decrease the lure of higher pay afforded by the private sector. Developing nations cannot afford to continually hire new employees to replace trained ones who have left the organization for better paying jobs.

It is in the best interests of all developing nations not presently active in any of the various forums associated with hydrography to increase their awareness of present and future hydrographic capabilities. In some cases it will simply be a matter of education to show how hydrography plays a critical role in economic and social development. Every nation should join the IHO to gain knowledge and benefits from association with members of the international hydrographic community. As already seen, the United Nations participates in a wide range of hydrographic related disciplines by means of councils, projects, etc.

The international community must establish mandatory, uniform standards. All charts will not have equivalent accuracies when people are trained at different locations under varying standards--lower standards inevitably lead to

lower quality. Conversely, standards cannot be made so high initially that they are incapable of being met by a large percentage of those nations expected to take on increased surveying and charting requirements in the future.

Although national authorities need to consider seriously the advantages and benefits derived from establishing a hydrographic office, there could be cases where such establishment would not be the best way to proceed. With a limited requirement it might be more advantageous and expedient to have the necessary survey work done by contract.

APPENDIX A

JOB DESCRIPTIONS OF LOWER LEVEL PERSONNEL

Senior Cartographer (Nautical)¹

Duties:

(1) Applies sound cartographic judgement in the selection, portrayal, and compilation of data to new charts and new editions using material which consists of, or is extracted from the following: analyzed and evaluated field reports, hydrographic surveys, photogrammetric manuscripts, foreign charts, Sailing Directions, Notice to Mariners, List of Lights, Caution Notes, and miscellaneous information.

(2) Applies the following cartographic techniques and employs instruments to compile various types of charts:

Computes, compares or checks computations for projection and grid coordinates.
Measures dimensions of source material to determine scale and selects method of enlargement or reduction to scale desired and reconciles geodetic control data as accurately as possible in poorly controlled areas.
Selects, gauges and specifies placement of appropriate type (letter sizes, line weight, numbers and colors), patterns and accents for geographic names, note titles, tables, and marine and air navigational zones.
Prepares detailed drafting or scribing and reproduction instructions and manuscripts.
Prepares a complete and accurate chart record of essential project recommendations, computations, sources and documents utilized and decisions rendered.
Recommends new and modified chart plans and specifications when necessitated by unpredictable problems encountered or new data received which affect chart projects under way.
Prepares reports, evaluates and recommends published hydrographic data for use as supplementary information to maps published by other government agencies.

(3) Examines and notes corrections and additions on drafted or scribed originals and reproduction proofs to assure accuracy, adequacy and completeness. Conducts a final check on the latest nautical information received, e.g., Notice to Mariners, List of Lights, Chart Standards. Certifies in chart record that such examination and investigation has been made prior to release of drafted or scribed originals and reproduction proofs.

(4) On a project basis is assigned special studies and provides guidance and supervision to lower grade cartographers.

¹Description from Defense Mapping Agency Hydrographic/Topographic Center, Field Offices Department, Providence Office, Hydrographic Division, West Warwick, Rhode Island

Cartographer (Nautical)²

Duties:

(1) Applies sound cartographic judgement in the application, portrayal and compilation of data to new charts and new editions using material which consists of, or is extracted from the following: analyzed and evaluated field reports, hydrographic surveys, photogrammetric manuscripts, foreign charts, Sailing Directions, Notice to Mariners, List of Lights, Cautions Notes, and miscellaneous information.

(2) Applies the following cartographic techniques and employs instruments to compile various types of charts:

Compares or checks computations for projections and grid coordinates.

Measures dimensions of source material to determine scale and selects method of enlargement or reduction to scale desired and reconciles geodetic control data as accurately as possible in poorly controlled areas.

Selects, gauges and specifies placement of appropriate type (letter sizes, line weight, numbers and colors), patterns and accents for geographic names, notes, titles, tables and marine and air navigational zones.

Prepares detailed drafting or scribing and reproduction instructions and manuscripts.

Prepares a complete and accurate chart record of essential project recommendations, computations, sources and documents utilized and decisions rendered.

(3) Examines and notes corrections and additions on drafted or scribed originals and reproduction proofs to assure accuracy, adequacy, clarity and complete conformity. Conducts a final check on the latest nautical information received, e.g., Notice to Mariners, List of Lights, Chart Standards. Certifies in chart record that such examination and investigation has been made prior to release of drafted or scribed originals and reproduction proofs.

²Description from Defense Mapping Agency Hydrographic/Topographic Center, Field Offices Department, Providence Office, Hydrographic Division, West Warwick, Rhode Island

Chief Survey Technician³

Responsibilities:

- (1) Maintain adequate levels of performance of survey department personnel in supporting and carrying out the survey operations of the vessel.
- (2) Proper care, maintenance, storage, and use of survey related equipment and instruments.
- (3) Maintenance of an adequate and accurate inventory of survey instruments, equipment, and supplies.
- (4) Efficient processing of survey data.
- (5) Cleanliness and order of all survey working and storage areas including plotting room, oceanographic laboratories, offices, etc.
- (6) Maintenance of complete and current technical library.

Duties:

- (1) Serve as technical assistant and advisor to Survey Planner in survey planning and operations.
- (2) Plan and direct the activities of survey department personnel, making work assignments and schedules, and assuring performance of assigned duties.
- (3) Coordinate and supervise field processing of survey data and samples.
- (4) Personally perform more complex and difficult technical work in connection with survey operations.
- (5) Maintain records of field equipment calibrations and, where possible, correct instrument deficiencies.
- (6) Prepare reports and other paper work as required.
- (7) May be required to act as "officer in charge" of a party engaged in survey or survey support activities.

³Description from National Ocean Service, Pacific Marine Center, Seattle, Washington

Senior Survey Technician⁴

Duties:

- (1) All duties listed for position of Survey Technician.
- (2) Provide primary review of field reduction of all survey data and samples, and provides technical competence in special projects or problems.
- (3) Act as "officer in charge" of a party engaged in survey or survey support activities.
- (4) Stand watches as required.
- (5) Perform mission-related duties as assigned.

⁴Description from National Ocean Service, Pacific Marine Center, Seattle, Washington

Survey Technician⁵

Duties:

(1) Serve on a launch or field party, engaged in survey or survey support operations, performing normally the following tasks:

Operate all hydrographic survey equipment, including sounding, navigation, automated data acquisition, and other associated equipment.
Carry out bottom sampling, bathythermographs, and other discrete oceanographic and sampling operations.
Observe, record, and reduce geodetic observations.
Set and describe geodetic marks.
Perform field photogrammetric operations.
Install and service tide gages.
Monitor all underway data gathering systems including echo sounder, gravity meter, magnetometer, etc.
Document, process, and preserve water, bottom, biological, etc. samples.
Make minor repairs to survey equipment and instruments.
Field process all survey data, including computer processing of hydrographic data.

- (2) Order and inventory supplies.
- (3) Train as surveyor in charge of hydrographic launch.
- (4) May be required to handle mooring lines.
- (5) Stand watches as required.
- (6) Perform other mission oriented duties as required.

⁵Description from National Ocean Service, Pacific Marine Center, Seattle, Washington

Assistant Survey Technician⁶

Duties:

Serve on a launch or field party engaged in survey or survey support operations as follows:

- Observe electronic positioning and sounding readings.
- Record hydrographic data.
- Observe sextant angles and plot sextant positions.
- Observe levels and observe distances using electronic devices.
- Recover geodetic control stations.
- Manually process field data including data reduction.
- Record horizontal control and level data.
- Build hydrographic signals.
- Perform technical drawing as required.
- Operate skiffs as required.
- Assist in the deployment and recovery of oceanographic, survey, and sampling equipment and instruments and monitor resultant data collection.
- Train in the use and operation of oceanographic equipment and horizontal control and leveling instruments.
- Systematically annotate, file, and care for field records and samples.
- May be required to assist in handling of mooring lines.
- Monitors all underway data gathering systems including echo sounder, gravity meter, magnetometer, etc.
- Document, process, and preserve water, bottom, etc., samples as required.
- Assist in the installation of tide gages.
- Train in field operation of automated hydrographic data acquisition systems and field photogrammetric operations.
- Service tide gages.
- Stand all required watches.
- Perform other mission related duties as assigned.

⁶Description from National Ocean Service, Pacific Marine Center, Seattle, Washington

Electronics Technician⁷

Duties:

- (1) Perform preventive and corrective maintenance on all the various types of electronic equipment and systems used by the agency. The equipment and systems may include--but are not limited to--data acquisition and processing systems, precise navigation systems, oceanographic instruments, and test equipment.
- (2) Provide technical briefs concerning the status of assignments to his/her designated technical supervisor. These briefs may include, but are not limited to: operational condition of equipment; adequacy of spare parts inventory; and need for procedural changes, equipment modifications and other changes to improve electronic support to the agency.
- (3) Initiate requisition of electronic supplies, parts, and repair services.
- (4) Conduct inspection and acceptance tests to insure adherence to specifications.
- (5) Accomplish installation and removal of electronic equipment.
- (6) Operate radio-telephone and radio-teletype equipment in accordance with documented procedures.

⁷Description from National Ocean Service, Pacific Marine Center, Seattle, Washington

APPENDIX B
ESTIMATED COST OUTLAYS

OPERATIONAL COSTS--YEAR ONE¹

First Time Costs

Salaries²

Director	\$42,000
Budget Specialist	30,000
Marine Specialist	30,000
Supervisory Hydrographer	35,000
Supervisory Cartographer	35,000
Tides Specialist	30,000
Secretary/Records Clerk	15,000

Salaries Subtotal	217,000
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Overtime	0
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Travel ³ (includes training)	10,000
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Operational Expenditures	10,000
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Materials & Supplies	5,000
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<u>First Time Costs Subtotal</u>	242,000
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<u>Recurring Costs From Previous Year</u>	<u>0</u>
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OPERATIONAL COSTS--YEAR ONE	\$242,000
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¹All costs are in 1984 U.S. Dollars.

²Salaries are based on U.S. standards. A scaling factor would need to be applied to compensate for possible differences in salary between the U.S. and other nations.

³Travel includes mandatory training costs for lower level employees incurred during first three years. Beginning in the fourth year, it will no longer reflect training costs.

OPERATIONAL COSTS--YEAR TWO*

First Time Costs

Salaries

Geodesist	\$30,000
Photogrammetrist	30,000
Survey Planner	30,000
Chart Planner	30,000
Sr. Hydrographer	30,000
Sr. Cartographer	30,000
Chief/Sr. Survey Tech.	25,000
2 Survey Techs @ \$ 21,000	42,000
Electronic Technician	21,000
ABS/Mechanic	17,500

Salaries Subtotal	285,500
Overtime	8,000
Travel (includes training)	65,000
Operational Expenditures	10,000
Materials & Supplies	0

First Time Costs Subtotal 368,500

Recurring Costs From Previous Year 242,000

OPERATIONAL COSTS--YEAR TWO \$610,500

*Expenditures itemized in Year One costs are assumed to remain constant through Year Two. Therefore, these recurring costs are shown in the Year Two costs as a single line entry.

OPERATIONAL COSTS--YEAR THREE⁵

First Time Costs

Salaries

Asst. Survey Technician	\$17,500
2 Cartographers @ \$ 25,000	50,000
Photographic Specialist	25,000
Processing Specialist	30,000

Salaries Subtotal	122,500
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Overtime	2,000
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Travel (includes training)	5,000
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Operational Expenditures	10,000
--------------------------	--------

(survey costs, launch ops.)

Materials, Supplies	2,500
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<u>First Time Costs Subtotal</u>	142,000
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<u>Recurring Costs From Previous Year</u>	<u>610,500</u>
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OPERATIONAL COSTS--YEAR THREE	\$752,500
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⁵Expenditures itemized in Year One and Year Two costs are assumed to remain constant through Year Three. Therefore, these recurring costs are shown in the Year Three costs as a single line entry.

OPERATIONAL COSTS--YEAR FOUR

First Time Costs

Salaries	\$ 0
Overtime	0
Travel ⁶	(-23,500)
Operational Expenditures	14,300
Materials & Supplies	4,500

<u>First Time Costs Subtotal</u>	(-4,700)
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<u>Recurring Costs From Previous Year</u>	<u>752,500</u>
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OPERATIONAL COSTS--YEAR FOUR	\$747,800
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⁶Advanced training costs are not allotted for the fourth year or thereafter. When this training is deemed necessary cost allocation will then need to be considered and will depend on the availability of outside sources of funding. The bulk of travel costs in Year Four and beyond are for per diem.

OPERATIONAL COSTS--YEAR FIVE

First Time Costs \$ 0

Recurring Costs From Previous Year

Salaries ⁷	625,000
Overtime	10,000
Travel	56,500
Operational Expenditures ⁸	44,300
Materials and Supplies	12,000

Recurring Costs Subtotal 747,800

OPERATIONAL COSTS--YEAR FIVE \$747,800

Note: Operational costs should remain relatively constant for subsequent years.

⁷Adjustments might be necessary as listed salary costs do not include an amount for yearly increases or promotions.

⁸Operational expenditures taken from Table IV after adjusting for salaries, travel, and materials/supplies which have been itemized separately above.

CAPITAL EQUIPMENT COSTS--YEAR ONE

Field Equipment

1 Survey Launch ⁹	\$150,000
2 Workboats w/ Motors	25,000
1 Office Trailer	12,000
1 Short-Range Electronic Positioning System	45,000
1 Level & Level Rod	2,000
1 Station Wagon	10,000
6 Sextants	2,500
2 Theodolites	12,000
4 Radios	8,000
4 Bubbler/ADR Tide Gages	14,000
2 Programmable Handheld Calculators	500

Office Equipment

Desks & Chairs	3,750
Drafting Tables	1,500
Light Table	1,700
Drafting Equipment	1,500
Miscellaneous Supplies	5,700

CAPITAL EQUIPMENT COSTS--YEAR ONE \$295,150

⁹Approximate price includes hull only. For fully equipped electronic vessel, which would include navigation and positioning equipment and full compliment of computer support, then additional costs of approximately \$100,000 would be incurred. This would mean an adjustment to the capital budget would be necessary, subtracting duplicated items.

CAPITAL EQUIPMENT COSTS--YEAR TWO

Field Equipment

1 Survey Echo Sounder	\$23,000
1 Portable Echo Sounder	3,500
1 Laser EDM (15 mile range)	17,500
1 Medium-Range Electronic Positioning System (Two Range System)	200,000
1 4-Wheel Drive Truck	12,000
1 Sound Velocity Sensor	4,500
Miscellaneous Survey Equipment	8,000

Office Equipment

Desks & Chairs	3,000
Drafting Tables	2,000
Light Table	1,700
Drafting Equipment	1,000
Office Safe	750
3 Flat Files (5 drawers ea)	830
Miscellaneous Supplies	3,000

CAPITAL EQUIPMENT COSTS--YEAR TWO	\$280,780
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CAPITAL EQUIPMENT COSTS--YEAR THREE

Field Equipment

Diving Support Equipment	4,000
1 Side Scan Sonar System	55,000
Current Meter	6,500

Office Equipment

Desks & Chairs	1,000
Drafting Tables	1,000
Drafting Equipment	2,000
Personal Computer w/Printer	3,000
Photographic/Darkroom Equip. ¹⁰	47,400

CAPITAL EQUIPMENT COSTS--YEAR THREE	\$119,900
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YEAR FOUR and beyond

Ongoing capital equipment costs annually will include replacement and new equipment. Common estimates for the life of electronic equipment are 6 to 7 years. Annual estimated requirement: \$20,000.

¹⁰Costs represented include a vertical camera, processor, vacuum frame with pump and exposing light, manual punch, densitometer, shop microscope, film cutter and 2000 Watt lights with timer. Not included are reversal film (\$358.00 for 42 in. x 100 ft. or \$306.88 for 36 in. x 100 ft.) and chemicals necessary to make rub-on color proofs. This information was obtained through telephone correspondence with Mr. Gene Hack of the Defense Mapping Agency Hydrographic/Topographic Center, Louisville Field Office, Photo Lab Chief.

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